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# A MANUAL

OF

# HYGIENE AND SANITATION.

BY

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AMERICAN MEDICAL ASSOCIATION,
ETC., ETC.

*THIRD EDITION, ENLARGED AND THOROUGHLY REVISED.*

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[illegible]

TO THE

MEMORY OF MY FATHER,

TO WHOM I OWE SO MUCH; TO WHOM I COULD REPAY SO LITTLE,

THIS VOLUME

IS MOST AFFECTIONATELY

DEDICATED.

99501

# PREFACE TO THE THIRD EDITION.

THAT Hygiene is undergoing rapid development as a science the author has appreciated more than once in this, the second revision of his text-book. Notwithstanding his care to keep the latter as concise as possible, and in spite of the fact that he has endeavored to prune carefully both the old growth and the new, it has increased by more than one-third of its original volume since its first appearance five years ago.

Some evidence of what Practical Hygiene and the employment of comparatively recent discoveries in its domain are doing for the welfare of the country is afforded in the introductory chapters by the data which were derived from the Reports of the United States Census of 1900.

It certainly is no mean achievement so to improve sanitary conditions within a single decade that for almost twenty-nine millions of people, or more than one-third of the total population, the death-rate for consumption has been lowered 24 per cent., that for typhoid fever 27 per cent., for diphtheria 50 per cent., and for malaria 54 per cent.; and that the reduction of the general death-rate for this same population represents a saving of almost fifty-two thousand human lives and the prevention of an incalculable amount of sickness per annum.

Unquestionably much of this betterment of conditions has been due to wider popular education in the principles of hygiene and the practice of sanitation, and, just as unquestionably, further improvement must depend upon instruction of the people along lines even broader and more thorough than ever before.

The author accordingly reiterates the aim and purpose of the volume, as expressed in the first edition, and continues to hope that, having found a place in extending general sanitary education, it will continue to merit the same kindly reception that was given to the preceding editions.

SENECA EGBERT.

OCTOBER, 1903.

# PREFACE TO THE FIRST EDITION.

FOR a number of years past it has seemed to the author that there was need for a manual or text-book which would give a plain statement of the fundamental principles and facts of Hygiene and Sanitation, together with such explanations and details, based on American practice, as would serve to make the work clear and readable.

Of all the medical sciences, that is clearly the most important which prevents disease instead of curing it, and deals with communities as well as with individuals. The vital interest and comparative simplicity of this science have already attracted the laity in great numbers, as well as the medical profession, and to this intelligent interest are largely due the remarkable advances which recent years have witnessed in methods of preserving the public health.

The desultory and often unauthoritative articles in the daily press or monthly magazines are scarcely fit material for satisfying this desire for knowledge, nor, on the other hand, can we expect any extensive study of the larger volumes on the subject. Smaller works exist, but they are either diffuse and lacking in system, or they detail methods and devices adopted abroad and out of harmony with conditions here. It is important for the medical student, at least, that the information given in such a text-book as the present should be as concise and systematic as possible, and that it should devote special attention to those conditions with which he is practically concerned.

For these reasons, and because I have as yet found nothing which exactly comprises my idea, I have ventured to offer this volume not only to my classes, but also to all who are desirous of doing what they can to better the health of themselves and of those about them. The volume deals with personal as well as public health.

In the preparation of the work the principal text-books have been freely consulted, as well as such recent magazine and other articles of authority as were pertinent. Quotations have been credited and references indicated, in order that the reader may know where to seek for further details or fuller information than the limitations of this work will permit. Indeed, I should do wrong were I to give any one the idea that this volume is thoroughly comprehensive, or even a compendium of the whole scope of hygiene or intended to be so. The science is already too great and too important to be treated entirely in a single volume, and, as it is so intimately concerned with every one's personal welfare, it is the author's earnest hope and desire that not only his students, but others as well may use this as an adjunct to further and more extensive reading; and that, inasmuch as hygiene is destined to be even more important in the future than it is now, all should make use of all possible sources of authoritative information.

Whatsoever may be the faults or shortcomings of the work, the labor expended upon it will not have been altogether in vain if it induces any one to take greater interest in the study of all that which pertains to "the preservation and promotion of health and the prevention of disease."

The illustrations have been selected with special reference to the text, and those of special devices or apparatus have been chosen as trustworthy representatives of their respective classes. For the four photo-micrographs of bacteria I am indebted to the skill and courtesy of Dr. William Gray, of Washington, D. C., to whom, and to all my other friends and associates who have aided me in the preparation of the work, I have many thanks to extend.

SENECA EGBERT.

MAY, 1898.

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# A MANUAL OF HYGIENE AND SANITATION.

## CHAPTER I.

### INTRODUCTION.

HYGIENE may be defined as the *art* and *science* that considers the preservation, promotion, and improvement of health and the prevention of disease. It treats of the laws of health in the broadest sense, and under the general term may be included a number of subdivisions. Thus, while Personal and Domestic Hygiene are respectively more closely related to the affairs of the individual and the household, Sanitary Science also finds larger fields and broader application in the domain of State Medicine and the Hygiene of Municipalities.

A little thought will show that under the general head we may consider: 1. The preservation and promotion of health. 2. Practical disinfection and the means of avoiding preventable diseases. 3. Adaptation of diet to the prevention and cure of perversions of nutrition. Under one or another of these themes will fall the discussion of the air we breathe, the water we drink, the food we eat, the soils and surroundings of our dwellings and communities; and at the same time the study of the means of recognizing, avoiding, correcting, or removing all impurities affecting any of these. In addition, there must be the study of climate and meteorology; of clothing and shelter; of the care of the sick, not only for their own sake, but that they may not endanger the well; the dangers of the abuse of stimulants, narcotics, etc.; the desirability of chaste and temperate living, exercise, rest, etc.

Parkes says that, "taking the word 'hygiene' in its largest sense, it signifies rules for the perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental or moral action; the mind is profoundly influenced by bodily conditions. [So is the moral conduct of individuals or communities.] For a perfect system of hygiene we must train the body, the intellect, and the moral faculties in a perfect and balanced order." Again, he says: "Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would be best arranged in an orderly series of this kind. The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being would be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs: of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; of decay, when, without actual disease, though doubtless in consequence of some chemical changes, molecular feebleness commences in some part or other, forerunning general decay and death. In these several epochs of his life the human being would have to be considered: *First*, in relation to the natural conditions which urround him, and which are essential for life, such as the ir he breathes, the water he drinks, etc.; in fact, in relaon to nature at large. *Second*, in his social and corporate relations, as a member of a community with certain customs, trades, etc.; subjected to social and political influences, sexual relations, etc. *Third*, in his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control. Even now, incomplete as hygiene is, such a work would, if followed, almost change the face of the world."

The student will readily see that the scope of the science is so vast that in a limited work like the present one it would be impossible to go over the entire ground completely and thoroughly. The most that may be attempted will be to discuss its fundamental laws as we now understand them, especially those that are most closely connected with the conscientious physician's duties and practice, and to show the reasons for and the advantages resulting from the pursuit of hygienic measures and sanitary methods based on those laws and our experience. Hygiene is, however, a science in the study of which common-sense must be freely used; and if the student will only bring this to his aid and add to it sincere attention, he will speedily find that there is little that is difficult, beyond his grasp, or less than really fascinating.

It has always been, as it always will be, an art to preserve health and to ward off disease. Hippocrates was among the first to define principles of public health or sanitation. He summed up the knowledge of his day concerning hygiene under six headings, viz.: Air, Aliment, Exercise and Rest, Sleep and Wakefulness, Repletion and Evacuation, and the Passions and Affections of the Mind; and he even pointed out that there must be an exact balance between food and exercise, and that "disease would result from excess in either direction."[1]

The excellence of the Mosaic code is acknowledged by all sanitary authorities, and the effects of its observance are seen to this day in the comparative longevity of the Hebrew race. The Greeks cultivated to the extreme both the physical and mental faculties, and had for their motto, *A sound mind in a sound body.* The Romans, in their aqueducts for conveying water to the city and in the Cloaca Maxima, have left examples of sanitary engineering which are, in certain respects, not yet surpassed. All of which serves to show that the ancients appreciated the importance of maintaining and improving health, and the influence of material conditions and environment upon sanitation.

The development of hygiene as a science, however, has been within comparatively recent years. Perhaps the first great impulse among English-speaking peoples, especially in matters pertaining to sanitation or "State Medicine," can be traced to the labors of Dr. William Farr, and to the establishment, through his efforts, of the British Registrar-General's Office in 1838.[2] Since then the task of determining the principles and laws of health has been carried on with unflagging zeal by workers both here and abroad, and within the last score of years or less the knowledge gained in the new study of the bacteria, especially that regarding the causation and nature of infectious diseases, has furnished us with a wealth of facts with and by which we may make the foundations of our science more secure and lasting.

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[1] Treatise on Airs, Waters, and Places. (About 400 B. C.)

[2] Note should be made, however, of the writings of Johannes Petrus Frank, in the first quarter of the nineteenth century and even earlier, and of Parent DuChatelet, between 1820 and 1836. Of the work of the former, it has been said that "It was the first orderly presentation of that which had hitherto been known upon these subjects, and was the first systematic effort to rescue from chaos such useful information as might be of service in the organization of a department of sanitary supervisors, or, as the author preferred to call them, medical police." A. C. Abbott, University Medical Magazine, July, 1900.

It would be wrong, nevertheless, to give the impression that hygiene is as yet an exact science. While it is rapidly attracting popular notice and attention, and has attained within comparatively recent years a dignity that it did not hitherto have in this new world, it is on a somewhat firmer basis in the older. The brightest minds of the day are busy with many of its problems, and facts and laws are being made clear that more firmly fix or may altogether change some of our beliefs and our practice. Especially is such new knowledge to be sought for in the study of the prevention of disease, the domain of bacteriology, the parasitic diseases, and the chemistry of the animal alkaloids and kindred compounds.

Perhaps a few statistics will help one to realize that the study is not in vain, and that the promise of the future is even more brilliant than the results and achievements of the past. Three centuries ago the death-rate of London was more than 80 per 1000; now it is about 20 per 1000. It is computed that in the eighteenth century—the one preceding the introduction of vaccination—fifty millions of people died in Europe of smallpox alone; now it is practically almost an extinct disease where vaccination is compulsory, as in Germany. In 1872 Sir John Simon estimated "that the deaths which occur in England are fully a third more numerous than they would be if our existing knowledge of the chief causes of disease were reasonably well applied throughout the country, and that of deaths which in this sense may be called preventable the average yearly number in England and Wales is about 120,000." In confirmation of the accuracy of this statement, official reports show that the annual death-rate of England and Wales, which averaged 22.6 per 1000 for the decade from 1862 to 1871 inclusive, fell to 18.9 for 1881, this giving a saving of 92,000 lives annually; while for 1889, even with the correction for the lowered birth-rate, it was only 17.9, indicating a yearly saving of at least 125,000 lives, and completely substantiating the above estimate of Simon. Moreover, the death-rate from the seven principal zymotic (infectious) diseases had dropped from an average of 4.11 for the period from 1861 to 1870 to 2.40 for 1881–1885, and that from typhoid fever from 0.39 per 1000 in 1869 to 0.137 in 1892. This for England and Wales. In Munich from 1866 to 1881 the average yearly hospital admissions of typhoid fever cases were 594, or 3.32 per 1000 of population, and the average deaths from this disease were 208, or 1.15 per 1000. From 1881 to 1888, following the introduction of improved systems of sewerage and a better water-supply, the average hospital admissions (typhoid) were 104, or 0.42 per 1000, and the average deaths were 40, or 0.16 per 1000 of population.

In this country a like improvement is to be noted, though it is only within the last few decades that much attention has been given to sanitary affairs. The death-rate of most of our cities is being progressively lowered, though the populations are constantly increased by large numbers of ignorant and uncleanly immigrants. Improved sanitary laws are being enacted and enforced, streets better paved and cared for, houses more wisely constructed and ventilated, more attention given to isolating the sick and protecting the well, and the people in general are awakening to the importance of improving as well as maintaining the public health. New York City has reduced her death-rate per thousand within the last census decade (1890 to 1900) from 25.4 to 20.4; Chicago, from 19.1 to 16.2; Boston, from 23.4 to 20.1, etc.[1]

According to the latest United States Census Report,[2] in New York City (Manhattan Borough) there were actually 4780 fewer deaths in 1900 than in 1891; in Cincinnati, 1200 less; in Buffalo 1000, and in Albany 600 less in the later than in the earlier year, with similar encouraging reports from many other cities, whose authorities attribute the good results as being due to advance in medical and surgical knowledge along the lines of preventive medicine, improved sanitary surroundings, improved water-supplies, cleaner streets, inspection of milk- and food-supplies, isolation and modern treatment of infectious diseases, additional public parks, etc.

The same census report tells us that in the so-called "registration-area," which embraces 86.7 per cent. of the total urban population of the United States living in cities of 8000 population or more, and 14 per cent. of the total rural population, and in which the statistics are fairly reliable and the death-rates comparable,—that in this area the death-rate from diphtheria has fallen from 70.1 per 100,000 of population in 1890 to 35.4 in 1900; from scarlet fever, from 13.6 to 11.6; from malarial fever, from 22.1 to 14.9; from typhoid fever, from 46.3 to 33.8; and from consumption, from 245.4 to 187.3 per 100,000 of population. For the registration-area, the general death-rate has fallen from 19.6 per 1000 in 1890 to 17.8 per 1000 in 1900, and this reduction, if applicable to the whole country, would represent a saving of over 136,000 lives annually. It does actually represent an annual saving in the registration-area, whose population in 1900 was 28,807,269, of more than 51,800 lives. Who then shall say that the study and practice of hygiene and sanitation,—of preventive medicine is of no practical value?

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[1] The importance of such statistics is not fully appreciated unless the reader remembers that in a city of, say, a million inhabitants a reduction of the death-rate one point means the saving of one thousand lives annually.

[2] Twelfth Census of the United States, 1900, vol. iii., Vital Statistics, Part I.

Nevertheless, there is still much to be done. Tuberculosis, which is said to cause from one-seventh to one-fourth of all the deaths in the civilized world, is practically a preventable disease, and we now not only know its cause, but also have efficient means for cure in a large proportion of cases, as well as for its general prevention. So with a number of the other infectious diseases. Almost every day marks an increase in our knowledge of their etiology and the securing of immunity from them; and not only must physicians make use of this knowledge as they acquire it, and employ their utmost endeavors to secure the enactment and enforcement of sanitary laws and regulations, but they must also realize that a large part of their work lies in the enlightenment and education of the people in all matters pertaining to the public health.[1]

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[1] It is encouraging to find that, although almost 11 per cent. of the whole number of deaths recorded in Philadelphia in 1900 were caused by consumption, a progressive and marked lowering of the death-rate from this disease in that city is taking place, and that, notwithstanding an increase in population of over 36.2 per cent., the fatalities from this disease are not much greater in number than they were sixteen or seventeen years ago. For example, the deaths from pulmonary tuberculosis in 1885 numbered 2821, and in 1886 were 2834, rates respectively of 2.97 nd 2.92 per 1000 living; while in 1900 there were only 2990 deaths, or a te of 2.31 per 1000 living.

The plague that was the bane of Europe centuries ago, and that has been a scourge to Asia since, still threatens us at our western gates, and is rife in some of our newly acquired colonial possessions. The infectivity of pneumonia is not appreciated by the laity nor by many physicians. In Chicago, in the first five months of 1903, there were more than twice as many deaths from this disease than from consumption, and more than 133 per cent. more than from all other communicable, contagious, or infectious diseases. We must not forget that this disease, which can be so pestilent, is "more or less limited to centres, corresponding in the main to the most densely populated areas, with their allied conditions of squalor and poverty,"[1] and that it is our duty, and for our own safety, to improve the sanitary conditions and environments of such areas and centres. With our present knowledge of the value of vaccination, there have been far too many epidemics of smallpox in the past few years. Carelessness in the application of protective measures has cost many lives and much money. There can be no safe cessation in prophylactic efforts. So also, each and every one of the communicable maladies must be continually investigated and studied, and all positive information gained concerning them must in turn be imparted to the people who need protection against them.

In the preparation for a study like the one on which we are about to enter there is some question as to just what may be the most advantageous order and arrangement of the subjects to be treated. For instance, it would be interesting to discuss our science in its relation, in turn, to the individual, the household, and the people in general —that is, personal, domestic, and public hygiene; and to show wherein the treatment of these subdivisions is similar and wherein they differ. Such a threefold consideration would be not only logical, but extremely instructive as well.

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[1] Anders, Journal of American Medical Association, May 9, 1903.

However, since the bacteria have been shown to have so important a part in many of the processes intimately connected with health and disease, it will doubtless be advisable to devote the next chapter to a brief review of the science of bacteriology. This done, it seems to the writer that we shall, as beginners, obtain a more comprehensive and thorough view of our subject if we pursue a method somewhat as follows: First, to discuss air, water, and food—three things essential to life—in the varying conditions and circumstances under which they may affect the physical welfare, either for good or bad, of the individual or of the community. Then to take up, in such order as may seem best, the other themes, such as climatology, habitations, disinfection and quarantine, disposal of sewage, clothing, exercise, school hygiene, etc., whose consideration, on account of their influence in the preservation of health and prevention of disease, is only a degree less important than the foregoing. In this way, while the whole ground may not be covered, the importance of the various subdivisions may be estimated in their relationship to one another, and we shall be the better prepared to pursue the study as opportunity may offer.

It is doubtless in place just here to review briefly the reasons why it is the special duty of the physician to be able to recognize and correct insanitary conditions wherever they may be found, and why he should make particular and constant study of the science in all its branches and developments.

Every true physician soon finds that the respect and affection of his patients and associates are worth far more than mere mercenary gain, and that his highest aim should be to prevent disease rather than simply to cure it; and, though this may seem to militate against his personal interests, he is unworthy the name of physician if his object and purpose be solely or primarily to make money. However, the observer quickly learns that in a community kept in good health and sanitary condition there will always be more or less need of a doctor's services in spite of every effort to prevent sickness, and that such a community will pay more promptly and more liberally for such services than one in which sanitary precautions are neglected. Health means ability to work and to earn good wages; and a healthy community means more business, more money, and more comforts. Moreover, as a rule, good wages insure prompt and willing payment of the doctor's bills as well as of others. We may note here the close relations existing between sanitary science and social and political economy—a relationship which is very intimate, as we shall see from time to time in our work, for as the physical condition of a people is bettered, it becomes more possible and more certain that they will likewise improve both mentally and morally.

Again, though the science of hygiene and sanitation is comparatively a new one, public attention is being strongly directed toward it, not only because it vitally interests every one, but because new discoveries and new applications of the laws pertaining to it are being constantly made, which are, in turn, swiftly given to the world by both the scientific and the popular press. This creates a demand for first-class teachers, which demand is bound to increase in the near future and promises materially to exceed the supply. In fact, within a very few years not only the medical, but also the academic and scientific colleges of the country will be compelled by public opinion to establish in their faculties well-equipped and liberally endowed chairs of hygiene and sanitary science, and it will be from the ranks of the educated physicians of the country that these teachers must naturally come. It will not be long before the people in general realize that it is fully as important that the college student or graduate be instructed how to do his part in taking care of the health of himself, his future family, and the community in which he is to reside, as that he shall be well taught in the abstract principles of theology or the classics of dead languages.

So, also, considerably more time and attention than are now accorded to it should be given to hygiene in the work of the various normal schools for teachers. The graduates of these schools will have much of the physical as well as the mental welfare of thousands of young and growing children in their keeping, and it is unquestionably their duty to prevent or obviate the ills of school-life as far as lies in their power, and to give instruction in and to inculcate habits of living which will continually tend to preserve and improve the physical health of those under their care.

Lastly, the time has come when a physician must necessarily have a knowledge of hygiene, preventive medicine, and sanitary science. Many States require as thorough examinations in this as in any other branch of medicine before granting the right to practise within their boundaries. So do the army, navy, and marine-hospital services of the government. Moreover, the people generally, as has been intimated, are awakening to an interest in sanitary matters and the prevention of disease, and expect their physicians to be well versed on all pertaining subjects; if they find one lacking in knowledge or interest in this respect, they are apt to think, rightly or wrongly, that he will also be deficient in the other branches of medicine.

Happily these causes all combine to place preventive on the same high plane with curative medicine, and the time is fast passing in which the chair of hygiene fails to have a primary place in any thorough medical school. May the day soon come when it shall have at least equal importance in the curriculum of all academic and normal colleges and schools!

It is evident that the successful physician and practical student of hygiene must have a thorough knowledge of three things: 1. Health and its laws; how to obtain and preserve it. This, of course, implies a knowledge of the human body and its functions, viz., of anatomy, physiology, and physiological chemistry. 2. He must study disease and its causes and nature. He must also understand the distinction between diseases due to causes external and those due to causes internal to the body; and that while some of these causes may be prevented or modified, others, with our present knowledge, may not be so readily overcome. 3. He must be conversant with and know how to use the therapeutic agents, both preventive and curative, that he has at his disposal, including not only drugs, but also all substances and forces that he can make efficacious to his purpose. The workman must know his tools to be able to use them intelligently.

Health is "that condition of the body and its organs necessary to the proper performance of their normal functions"; and disease may be defined as "a condition of the body marked by inharmonious action of one or more of the various tissues or organs, owing to abnormal condition or structural change." It is, accordingly, well to consider briefly the nature and causes of disease, that we may the better understand the influence upon its prevention or production of all those varying factors, phases, and conditions of our environment which we hope to study in our work.

Disease is an entity, not a spiritual thing; a condition, not a theory. Consequently it is to be fought and, if possible, conquered with matter, force, and physical means, though not necessarily with violence. In fact, when once we understand the minuteness and delicate structure of the ultimate cells and tissues affected, we realize that oftentimes the gentlest application of the forces and means employed may be the most helpful and efficient. But when one has seen the ravages caused by it as revealed in the pathological laboratory and at autopsies, not to speak of its manifestations in the living as seen in the sick-room and in hospitals, I am sure that he cannot logically, even for a moment, give credence to those who proclaim that it can be dissipated by the mere action of mind or of faith; nor to those others who declare that by subdividing and diluting and subdividing again infinitesimally a single grain of substance, whether primarily powerful or inert, you endow it with a miraculous power to remove the "ills that flesh is heir to." Virchow gave a priceless boon to modern medicine in his theory of cellular pathology and in showing its superiority to the old humoral theories and *a priori* reasoning. He wrote "whatever outside of a cell acts upon it (abnormally) works a mechanical or chemical change within it, which change is disorder or disease." The sooner we realize that the laws of physics and chemistry govern cell life action and, consequently, the functions and organs of the body, the more accurate will be the treatment and the more certain the prevention of disease.

For convenience' sake, diseases may be divided into two main classes, somewhat different in their origin, nature, and character, although the line between the two is not always clearly marked. Diseases of the first class arise *within* the body, and may be called *autogenetic*. They are usually due to some alteration or disturbance of nutrition and assimilation, such as irregular absorption of products of digestion, or of function, such as that of elimination, to either of which, as well as to other similar causes, various auto-intoxications may be due. The second class comprises those which are due to causes from *without*, favored, it may be, by either internal or external predisposing conditions, but each malady of necessity depending upon the reception or inoculation of the special cause, which cause has the power of reproduction and development, of vitality and virulence. Such diseases are called *contagious*, *infectious*, *specific*, *inoculable*, or *zymotic*.

A third class or a subdivision might also be indicated, which would include those disturbances which are almost purely psychical and whose symptoms are largely notional and the result of perverted imagination or coördination. But it is a question whether the primary cause of almost all such disorders is not an altered and abnormal nutrition or functioning of the general nervous economy of the body, and the symptoms simply reflex manifestations of irritative disturbances of distant organs.

In the first class, with our present knowledge, we may place such maladies as rheumatism, gout, diabetes, neurasthenia, etc.; while into the second will obviously fall all that are now known to be due to living "germs" or organisms, such as cholera, typhoid fever, malaria, etc. However, we must not overlook the impulses often given to the causation of certain members of the second class by faulty conditions of nutrition or assimilation, as is especially exemplified in many cases of tuberculosis. The character of the soil may influence the growth and product of a plant almost as much as the species itself, and so the difference in constitution and tissue of individuals may materially determine the variation in symptoms and virulence so often manifested by an infectious malady.

**Prophylaxis** is "the use of hygienic or other precautions conducive to the prevention of disease"; or it may be defined as "a series of methods or procedures whereby disease is restricted and prevented by suppressing or removing its predisposing conditions, and destroying or modifying the exciting causes." Its first function of suppressing or removing predisposing conditions is accomplished by *sanitation;* the second, that of destroying or modifying exciting causes, is carried out by *disinfection.* The term "predisposing conditions" should be used instead of "predisposing causes," because these conditions cannot in themselves originate a disease, though they may make the system more susceptible to the exciting causes of a disease. For example, the predisposing factors of tuberculosis—"privation, depression, and excess"—are conditions, and though they often prepare the tissues for the development of the malady, it can only occur after infection by the exciting cause, viz., the specific tubercle bacillus.

As we have, as yet, little definite knowledge of the exact nature of the exciting causes of autogenetic diseases, they being developed and elaborated within the body, and as disinfection, or the destruction and modification of exciting causes, is an important feature of prophylaxis, we at present naturally look for more immediate and satisfactory results in the application of prophylaxis to the second class of diseases; but this does not prevent or restrict the employment of certain prophylactic measures in regard to the first class, such as the selection of proper diet, clothing, climate, etc., and the removal or counteracting of all causes favoring malnutrition or imperfect and improper functional activity. We may therefore say that sanitation is the defensive, disinfection the aggressive part of prophylaxis.

To suppress and remove predisposing conditions and to prepare the body to resist and repel the action of exciting causes, we must not only strengthen its powers of resistance, but also make all external media as favorable to health and as hostile to the exciting causes as possible. The defensive powers of the body must lie in the individual cells and tissues of the body, including the vital fluids, and it is but natural to suppose that this repellent action to noxious substances is performed best when the cells and tissues are in most perfect health and most vigorous condition. This is not only good logic, but all experience and scientific research go to show that it has a firm foundation in fact.

We shall soon learn that purity of the external media and environment of the body is essential to its welfare and that of its component tissues, and that conditions of impurity in these media predispose to disease. We shall also learn that a proper and sufficient supply of wholesome food is essential to health, and that certain other factors, as sex, age, clothing, climate, etc., may act for good or ill in the determination of the balance between health and disease. In other words, if we strengthen the resistant powers of the system to the fullest extent and remove all predisposing conditions, in all probability the exciting causes will be inoperative in most cases, and there will be no incurrence of disease. This is the essence of sanitation: to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body safe and free from depressant factors. This applies equally to both classes of disease; for with healthy cells and proper food there will not be faulty nutrition and assimilation or improper functioning and the consequent production of the exciting causes of autogenetic disease; and with a vigorous resistance and wholesome environment there is little opportunity for the germs of infectious maladies to obtain a foothold within the system long enough to reproduce themselves and cause their characteristic disorders. The best means, therefore, of preventing disease is to learn and apply the best methods of attaining and retaining a healthy and vigorous state of the system, viz., to determine and observe the laws of hygiene.

# CHAPTER II.

## BACTERIOLOGY.

THE increase in the knowledge concerning the lowest forms of life, and the discovery within recent years that these often have a causative action in the excitation of many maladies, have greatly facilitated the study of the prevention of disease. In fact, it is largely to this advance in knowledge and to the confirmation of the germ theory that much of the success of modern hygiene and sanitation is due. In addition, many species of bacteria are of extreme importance because their function is that of scavengers, continually working to remove and convert the useless and harmful wastes of the world into matters of high value as food for organic life; while still other kinds are being found to have great value in many strictly commercial processes. A review of the chief facts concerning them will therefore be in place at this time.

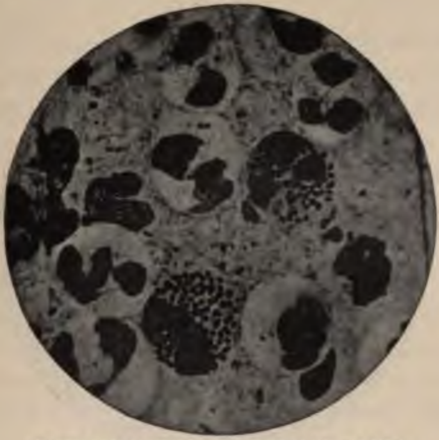
The unicellular vegetal micro-organisms divide themselves into two general classes with respect to their manner of reproduction, viz., those that multiply by budding —the *blastomycetes*—and those that increase by simple division or fission—the *schizomycetes*. In the first class we have the hyphomycetes or mould-fungi, and the saccharomycetes or yeasts, examples of these being familiar to every one. However, it is with the fission-fungi, or *bacteria* as they are now more generally known, that we are most concerned as sanitarians, since they practically include almost all those vegetal micro-organisms that are more or less closely connected with the production of disease as well as with the removal of offensive matter. Comparatively few of the yeasts and moulds are pathogenic, and then only indirectly or in a minor degree.

*Bacteriology,* then, is the science of those unicellular vegetal micro-organisms that multiply by direct division (fission), or, as occasionally happens, by the development of spores. Its study consists in the examination by means of the microscope of the form and method of growth of these minute plants, in their artificial cultivation on or in suitable media, and in the determination of the effects of the inoculation of pure cultures upon animals. To these may be added another field of research that gives promise of development in the near future, viz., the study of the chemistry of the bacterial products and of the reactions produced by their presence in culture-media and in living tissues.

Although more than two centuries have elapsed since the discovery of the bacteria by Leeuwenhoek (about 1680), and though Plenciz advanced as early as 1762 what is practically the germ theory of to-day, most of our knowledge concerning the physiology, methods of cultivation, and differentiation of the bacteria have been acquired within little more than twenty years. It is true that some earlier advance had been made in sterilization, and that Cohn, by establishing the fact of spore-formation, demolished the last arguments in favor of spontaneous generation, and confirmed the science of bacteriology; but until the years just preceding the last two decades we had but little knowledge as to the means of separating and isolating the different species and making ure cultures, or of preparing culture-media, staining, etc.

As has been intimated, the bacteria are unicellular organisms, usually multiplying by a process of cell-elongation and fission. Being without chlorophyll, they cannot absorb and decompose carbon dioxide and ammonia, as do the higher plants ; but require for their growth and nutrition organic matter—usually soluble albumin—in the presence of moisture.[1] Hence they must be either saprophytes or parasites. As the combination of albuminous organic matter and water is extremely common, so the distribution of the bacteria over the earth is widespread and practically universal.

FIG. 1.



Micrococci (gonococci) in pus-cells. × 1000.

Some of the bacteria may, under adverse conditions, such as lack of nutriment or of moisture, too alkaline or too acid a medium, extremes of temperature, etc., or on the other hand, as a result of the attainment of a stage of maximum development, produce spores which are much more strongly resistant to deleterious influences than the bacteria themselves. In this way the spore-forming species may often survive the action of disinfectants or other agencies that are sufficient to destroy other bacteria. Upon the resumption or recurrence of favorable conditions the spores develop into cells similar in form and nature to their parent cells. It is to be remembered that spores do not reproduce spores, and that "a single cell produces but one spore."[1]

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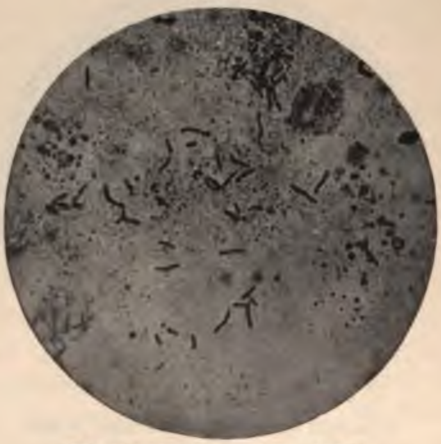
[1] It will be understood that these statements and many of those to follow are more or less general, and that certain species of the bacteria may present notable exceptions.

FIG. 2.



Tubercle bacilli in sputum. × 1000.

Under the microscope the spores are seen as highly refractive spherical bodies that stain with difficulty, and evidently have a very resistant envelope, probably of cellulose. The interior of bacteria and spores is protoplasm. far as is positively known at this time, only certain of bacilli form spores, while a few of the spirilla and one or two species of micrococci probably have the same faculty.

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[1] Abbott, Principles of Bacteriology, 1st ed., p. 31.

Again, under certain peculiar conditions some organisms may develop another morphological change, the so-called involution-forms. These are doubtless pathologically distorted cells, with probably diminished resisting powers, but which will revert to the normal type under favorable conditions, providing the unfavorable environment does not kill them.

Lastly, at times certain individuals of a species seem to have departed from the typical form, but these departures are only different phases in the normal development. Thus a young bacillus may be shorter than the adult and look much like a coccus, or a coccus about to undergo division may be oval in shape and considerably larger than the quiescent members of its species. But one form of bacteria never permanently takes that of another—micrococci are always micrococci, bacilli always bacilli, etc.

A thoroughly scientific classification of the bacteria is scarcely possible as yet, owing to our incomplete knowledge of their character, method of growth, physiology, etc. However, there are a number of ways in which we may subdivide them, none of them exactly scientific, perhaps, but still sufficiently accurate and convenient for our purpose. If we consider the bacteria as to form, we have: (*a*) *micrococci*, spherical in shape; (*b*) *bacilli*, which have one diameter longer than another; and (*c*) *spirilla*, spirals or segment of spirals.[1] We shall have more to say hereafter of the characteristics of each of these subdivisions.

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[1] Accurately speaking, some of the so-called higher bacteria have more elaborate development and distinction as to form, but as our present discussion has almost entirely to do with the phenomena of the lower and simpler bacteria the former may henceforth be omitted from the discussion.

Accordingly as they live best with or without air or oxygen they are *aërobic* or *anaërobic.* Again, they may be named according to their product—*e. g.*, some produce colors, *chromogenic;* others pus, *pyogenic*, etc. Lastly, they exist and grow either as *saprophytes* upon dead, or as *parasites* upon living organic matter. We also say that an organism is *optional* or *facultative* when it is at one time a saprophyte and at another a parasite, or at one time aërobic and again anaërobic; and that it is *obligate* when it has not this property of changing its nature according to surrounding conditions.

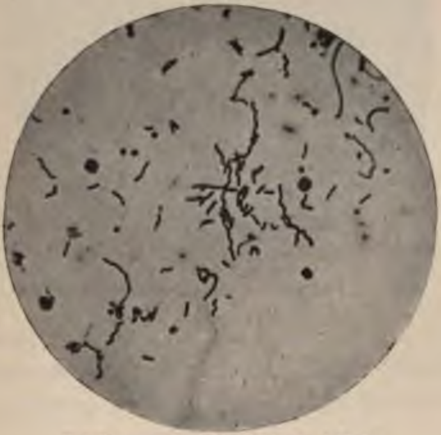
Some of the micrococci are named according to the manner in which they grow. If in pairs, they are called *diplococci;* in fours, *tetracocci;* in threads, *streptococci*, etc. Groups or masses of micrococci or bacilli held together by a gelatinous substance are called *zoöglea.* With one or two exceptions we know but little about the spirilla. The germ of cholera—the comma bacillus (?)—belongs to this class, and the cause of relapsing fever is also probably a spirillum.

Most of the bacteria thrive best in culture-media that are neutral or only slightly alkaline, though a few species seem to do better in slightly acid surroundings. So, also, they do best at temperatures ranging between 20° and 40° C. (68° and 104° F.), though they may grow at any temperature between 5° and 43° C. (41° and 109.4° F.). Any marked deviation in the culture-media from the neutral point or continued exposure to extremes of temperature may either check the growth of the organisms altogether, and eventually destroy them, or may cause spore-formation, or the production of involution-forms, or a change in the composition and the character of the chemical products which the bacteria normally produce.

This also holds good with respect to any other condition or substance that may be deleterious to the bacteria in their normal state; wherefore we shall see that it is important as having a decided influence in altering the virulence of pathogenic bacteria and in suggesting methods for bringing about a condition of immunity to their attacks.

As it is rare to find isolated individual species anywhere except in pure cultures artificially prepared, it is evident that we must devise some way of separating the different kinds of organisms one from another. This is best accomplished by the method suggested by Koch, viz., to introduce the mixed kinds into some melted culture-medium, like nutrient gelatin, which solidifies on cooling, but whose melting-point is not sufficiently high to destroy the vitality of the germs. If the fluid be well shaken, the various species will be distributed through it, and upon cooling each individual or group (zoöglea) of individuals

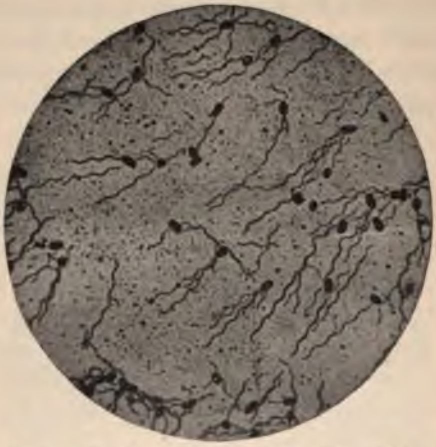
FIG. 3.



Spirillum of Asiatic cholera. × 1000.

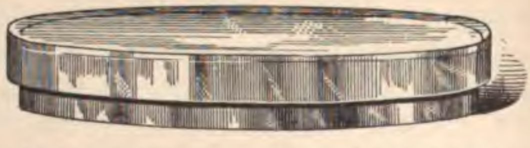
of the same kind will be fixed in its place and become the starting-point of a *colony* of that special kind. Moreover, if the gelatin before cooling be poured upon sterilized glass plates or into flat (Petri) dishes (Fig. 5), the subsequent work of counting, examining, and making cultures from the colonies thus secured will be greatly facilitated, while by transplanting and repeating the process one or more times, absolutely pure cultures of each species in the original mixture may be obtained.

Fig. 4.



Bacilli of hog cholera, showing flagella. × 1000.

Fig. 5.

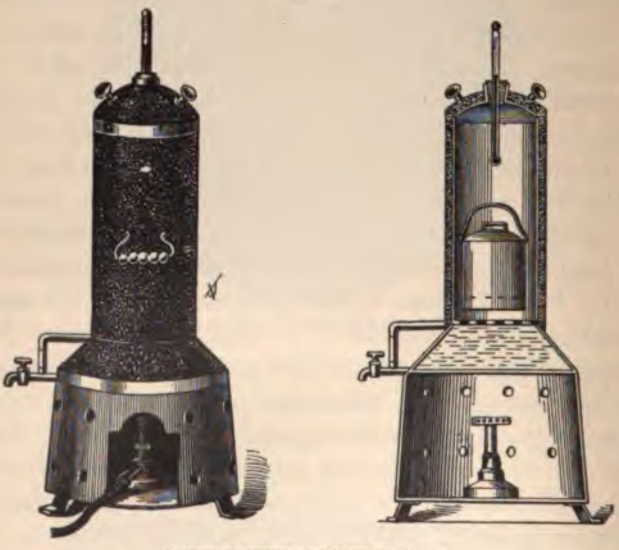


Petri double dish (now generally used instead of plates).

Special care must be taken in this, as in all other bacteriological methods or operations, to prevent contamination of cultures, media, or apparatus by other organisms which are almost omnipresent, and which would prevent accurate results or deductions were they not rigidly excluded or destroyed. Obviously, we may not use chemical disinfectants or antiseptics as a means of destroying the interfering microbes, for such procedure would kill or inhibit the growth of the bacteria we desire to cultivate; but we must sterilize by heat all the articles used, together with their contents. This, if properly done, does not affect the nutrient properties of the culture-media, while it does remove the danger of contamination already present.

In sterilizing we may use either dry or moist heat, the latter being far more preferable in most cases, since to be effectual it does not require so high a temperature nor so long a time as does the former. Moist heat, especially in the form of steam, is more penetrating than dry heat; beside, dry heat must be of so high a temperature that it may render useless for culture purposes such substances as nutrient gelatin. Glassware and the like, however, may be quickly and advantageously sterilized by dry heat. On the other hand, certain substances, like blood-serum, are spoiled for culture purposes by moist heat continued sufficiently long to kill the spores possibly present, as the latter require a higher temperature or more prolonged heating to sterilize them than the bacteria without spores. Resort is therefore had to fractional sterilization in such cases, exposing the materials for only a short time to a temperature just sufficient to destroy the bacteria, repeating the process after an interval, say twenty-four hours, which is presumably sufficient to allow the spores to develop into bacteria; and again a third time, after a like interval, to insure absolute sterilization. Previous to sterilizing the culture-media and apparatus we prevent the subsequent access of contaminating germs to the interior of tubes and vessels by plugs or stoppers of cotton-wool, covering these, when necessary, with rubber caps to prevent the evaporation of fluids or of moisture from the gelatin, etc.

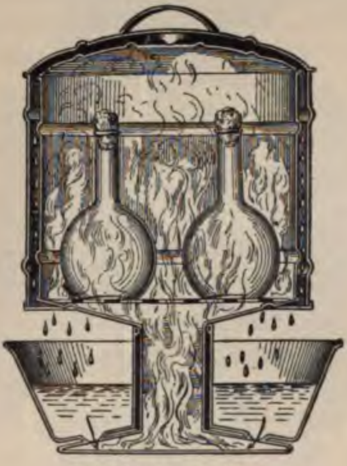
FIG. 6.



Steam sterilizer, pattern of Koch.

As a basis for a number of culture-media we may use beef-broth or bouillon, which is a fluid especially favorable to bacterial growth in that it contains an abundance of albumin in solution. When a solid medium is desired, either gelatin or agar-agar (a gelatin-like substance obtained from Japan) may be added to bouillon, giving nutrient gelatin and nutrient agar-agar. Of these, the gelatin has a melting-point below the temperature of the human body, while that of agar is above; consequently we employ the latter when it is desired to cultivate germs that grow best at the body temperature, although the development of most bacteria is usually more rapid and characteristic upon gelatin. Blood-serum sterilized and solidified is also used for the cultivation of certain organisms, like the diphtheria bacillus; and there are certain others which can only be identified by their difference in growth upon boiled potato, milk, etc.

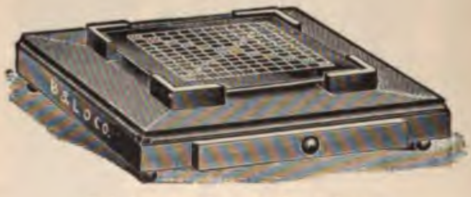
FIG. 7.



Arnold steam sterilizer.

The differentiation of the various species of bacteria is to be made by noting their appearance and form under the microscope, whether they are motile or not, how they take different stains, etc.; by observing their methods of growth in or upon different culture-media, and the color and appearance of the colonies; by noting whether they are aërobic or anaërobic, or facultative, and at what temperatures they thrive best, etc.; and finally by studying their action and the effect of their products upon living animals. In this way we may determine the characteristics of each individual or species, and will eventually have the data for a strictly scientific classification of the bacteria in general. For example, the organisms causing suppuration are usually micrococci, occurring in clusters (staphylococci) or in chains (streptococci); the cause of typhoid fever is a bacillus, and the cholera germ belongs to the spirilla. The tubercle bacillus stains with marked difficulty, but when stained is not readily decolorized by a weak solution of nitric acid, as are almost all other bacilli. Some bacteria liquefy nutrient gelatin, others do not, and almost none liquefy agar-agar. This liquefaction is not a melting, but rather a probable peptonization, since the gelatin will not solidify after this occurs, as it does after being subjected to moderate warming. Again, some bacteria produce one particular color or chemical substance in the presence of oxygen, and another in its absence; some produce color only in the light, others only in the dark, etc. Finally, different pathogenic microbes cause different maladies when inoculated in animals or human beings,

FIG. 8.

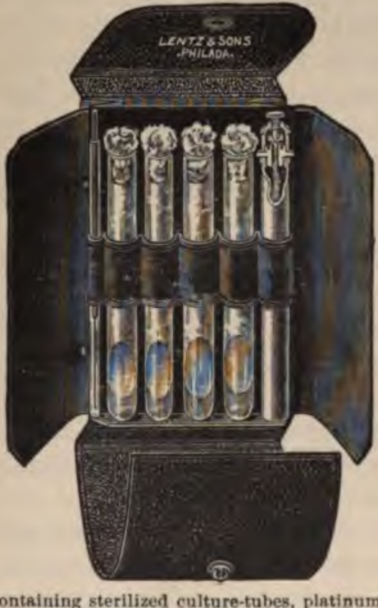


Ruled square for counting colonies.

and the same germ may produce different results in animals of different species or families.[1]

The subdivision of the bacteria into saprophytes and parasites has already been noted. Therefore, it must be remembered that not all of these microscopic plants are disease-producers; much the larger proportion, in fact, being benefactors rather than otherwise to the human race.

FIG. 9.



Pocket-case containing sterilized culture-tubes, platinum needle, and alcohol lamp, used for obtaining cultures for diagnosis, etc.

The function of many of the saprophytic organisms is to change dead organic matter into simpler chemical compounds and ultimately into end-products such as carbon dioxide, ammonia, and water, these latter substances being once more utilized in the nutrition of the higher forms of vegetable life, which are in turn necessary to the existence of the animal life upon the globe. One should also understand that some of the saprophytes in the soil seem to possess a constructive or synthetic power, elaborating more complex plant-foods from the simple compounds mentioned. Indeed, it is only when the student of hygiene fairly realizes the wide scope of the functions of these minute but almost omnipresent scavengers that he will comprehend the important part they play in the purification of our environment. In the air they possibly help the oxygen to destroy the harmful effluvia and exhalations of men and animals and the floating débris of organic substances; in the soil, the common receptacle of the wastes and refuse of vital activity, they quickly and continually convert these noxious additions into foods of the highest value to growing plants; in running streams and quiet pools they are of the greatest importance in the removal of the dangerous impurities washed from the surface of the land or recklessly discharged from human habitations, factories, and the like. And not only do the saprophytes help mankind in this way, but members of the class are beneficent in many others. For example, they enable those plants, the leguminosæ, which yield us the largest supply of vegetable proteids, to derive much of their nitrogen almost directly from the atmosphere; they have much to do with the flavor and value of dairy products, and uses in which they may be employed in the domestic and commercial affairs of life are being newly announced from day to day. Thus we find the bacteria of this class, which comprises by far the greater number of known species, to be our benefactors and indispensable servants both in preventing the accumulation of noxious and harmful substances upon the earth and in helping to produce the food which we eat and many things that we need and use in our daily life.

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[1] See Kenwood's Hygienic Laboratory, pp. 466–470; also McFarland's Pathogenic Bacteria, pp. 46–57.

The parasitic bacteria, on the other hand, have their habitat in or upon highly organized living matter, and exist at its expense. They also produce in their growth poisonous substances, called *toxins* and *toxalbumins*, that are either locally or generally harmful to the organism that is their host. It is needless to say that it is in this class that we find the disease germs, or *pathogens* as some would call them. It should not be forgotten, however, that the saprophytes, in bringing about the decomposition of complex organic bodies, may also produce *ptomaïns*, which may or may not be toxic to animal life. Of these latter, we may instance as good examples the cadaveric poison of the dissecting-room or the dangerous tyrotoxicon, a by no means uncommon product in the decomposition of milk or ice-cream. But though ptomaïns may be more or less characteristic of the respective bacteria that produce them, each varies in its composition and properties according to the substance upon or in which it is produced, while the toxins are specific derivatives or "active principles" of their respective micro-organisms. In other words, different kinds of saprophytes may produce the same ptomaïn from a given organic substance, but each toxin is the product of its own particular species of bacteria and is independent of the latter's place of growth or environment.

Considering for the present the pathogenic bacteria alone, we are naturally brought to the discussion of the *germ theory*, which is, that the exciting cause of each

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contagious or infectious disease is some specific parasitic organism, and that these diseases are each communicated only by the transferrence to and development of the particular parasite or germ within or upon the tissues of the infected individual. Consequently such diseases are transmitted from one person to another, or in some cases from animals to men or *vice versa*, by means of those micro-organisms, and the transferrence is by air, water, food, or other fomites, or by direct contact. It is evident that if acquired knowledge establishes the truth of this theory, the prevention of infectious diseases is greatly simplified and becomes merely a matter of combining effective sanitation, of which we have spoken, with the destruction of the specific exciting causes—*i. e.*, disinfection. Nor is it essential that we any longer make a distinction between the terms contagious, infectious, zymotic, and specific, that formerly obtained, since they may practically be used synonymously. The first of these terms used to be applied to those diseases which were believed to be transmitted most frequently by direct contact, and *infectious* to those of which the transmission was usually by fomites. But we know that germs of the former class may be transmitted by air, water, food, etc., and those of the latter by personal contact, though the reverse is what usually happens in the respective cases. Occasionally disease occurs also by *inoculation*, the exciting organisms being introduced into the body either accidentally or intentionally through some wound in the protecting skin or mucous membrane. The term *zymotic* was formerly applied to those diseases occurring in epidemics, and which were supposed to be due to fermentative processes; if used at all, it should be given to any disease due to a living germ. The term *specific* should only be given to those maladies which have a specific origin—*i. e.*, which have been proved to be due to a single organism.

In this connection we may define an *epidemic* as "an outbreak of a communicable or infectious disease affecting a dozen or more individuals in quick succession before the recovery of the first case, whether arising from a single focus or several foci in a neighborhood."[1] An *endemic* disease is one occurring more or less constantly in a certain locality. When an epidemic extends over a very large territory, it is said to be *pandemic.*

That all communicable diseases are due to vegetal germs or kindred animal organisms is more than probable, and while there are some for which this has not been fully proved, it is scarcely possible that any of these may arise from insanitary conditions without the presence of a living causative organism.

The reasons for believing in the germ theory are based on empirical and logical facts as well as theoretical hypotheses. Ignoring at present the scientific research work already done, it is evident that the substance that causes a disease—the *contagium*—must, when introduced into a susceptible person or animal, increase in quantity to an enormous extent. Note, for instance, the large quantity of actively virulent matter thrown off from a case of smallpox or scarlet fever, and yet how very little is required to initiate an attack of the disease. No inert chemical substance has the power of being increased to such an extent by simply finding lodgment in a suitable medium.

The poison of contagion, whatever it may be, evidently must have life and the power of reproduction. Moreover, these causes of disease, when freed from the body, may be carried long distances, and may still retain for years their power for harm, only waiting a suitable field in which to multiply and cause the same malady as before. Such causes must therefore be capable of entering a state in which vitality is latent, and in which the reproductive functions are for a time inactive. But it is known that the spores of many bacteria, and sometimes the bacteria themselves, may be carried afar, kept for long periods of time, and even exposed to wide extremes of temperature, without being killed or losing their power of reproduction and rapid multiplication. Again, we know that substances that are poisonous to or that prevent the development of these bacteria and kindred low forms of life, do, when properly used, prevent or remove the danger of contagion and infection.

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[1] Committee of American Public Health Association, 1898.

There is also in the development and progress of infectious disease a direct analogy to the phenomena of fermentation, whose causative organisms are of the same order as these which we are considering; the same rapid multiplication of cells in suitable media at proper temperatures, a period of incubation, and then changes in the infected body or host, which, after going on to a certain extent, check the further development and multiplication of the organism. What it is in the medium that checks the growth of the germ we may not be able to determine *a priori*, but we may assume it to be something hostile to the contagium, as alcohol above a certain percentage in the fermenting medium is deterrent to the further growth of the yeast-cell.

Lastly, if the proof of Koch's postulates is essential to the acceptance of a given micro-organism as the cause of a given disease, we must believe, on the other hand, that a certain germ is *a* cause, if not the only one, of a certain malady if these postulates be proved with respect to the germ and the malady.

To determine whether an organism is or is not pathogenic it is necessary to experiment on living animals. To do this we must use pure cultures of the organism and carry out all our processes, including inoculations and autopsies, under strictly antiseptic precautions. For example, we may examine microscopically the blood and various tissues of a diseased animal; if bacteria be present in any of these, we make cultures from them, and if more than one kind of bacteria be present, the various kinds must be isolated and pure cultures made from each kind. When a pure culture is at last obtained, it may be studied both microscopically and as to its characteristics in various media and at different temperatures. Finally, healthy animals known to be susceptible to the disease in question are inoculated from the pure culture, and after the period of incubation carefully watched for symptoms of the disease. Should these manifest themselves, the animal is killed and its blood and tissues carefully examined for the inoculated organisms. A similar study is to be made of each species isolated from the first animal.

The *postulates of Koch*, which are necessary to prove that a germ is the cause of a given disease, are: 1. The micro-organism must be found in the blood, lymph, or tissues of a person or animal sick or dead of the disease. 2. The micro-organism must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside of the animal body. These cultivations must be carried on through several generations until a pure culture of the germ is obtained. 3. A pure culture thus obtained must, when introduced into a healthy and susceptible animal, produce the disease in question. 4. In the inoculated animal the same organism must again be found.

In the case of many diseases peculiar to human beings alone the third condition must remain undetermined and our chain of proof be broken, because we should not endanger human health or life by experimental inoculations. But in diseases common to men and animals the experiments necessary can be completely carried out, and where a germ can be proved to be the cause, according to these postulates, of the malady in animals, we can also fairly conclude that it is the cause of the same disease in human beings. The specific germs of a number of maladies common to man and beast have thus been determined, together with those of a large number of affections peculiar to animals alone.

Granting that a certain organism be pathogenic, infection by it will depend not only upon the susceptibility of the animal or person concerned, but also upon the method of entrance into the body, the number of microbes introduced and present, and especially upon their degree of virulence. Thus, the tubercle bacilli produce effects of different character and gravity in different tissues, and it needs no argument to show that while the normal resistance of the body may be all-sufficient to overcome a few vicious germs taken in with the air, food, or drink, it may be entirely inadequate to resist and may quickly succumb to large numbers of the same enemy, especially if the virulence of the latter be enhanced, as we now know it may be, by various factors that thus assume great sanitary importance. Not the least of these are temperature and nutrient conditions, and change in potency due to growth and development in certain animal or human bodies.

After infection or the reception of the contagium by a susceptible animal or person there is a *period of incubation* before the manifestation of the characteristic symptoms of the disease. This period is variable according to the disease or kind of germ, and during it the micro-organisms rapidly increase in numbers and their consequent power for evil.

After the pathological process is well under way we shall probably find one of two conditions existing, viz., that "in which the blood is the chief field of activity of the organisms,"[1] and the vessels of the victim are swarming with the microbes—in other words, a true *septicæmia;* or else one in which "the poisonous results are not necessarily accompanied by the growth of organisms in the tissues," these latter, in all likelihood, not extending beyond the lymphatic glands nearest to the point of inoculation—*i. e.*, a *toxæmia.* A good example of the former condition is furnished by a case of anthrax or of pyæmia, and of the latter by diphtheria. However, we shall find in either condition that if we isolate the peculiar product or toxin of the specific germ, either from artificial growths upon or in culture-media, or from the blood or tissues of an animal sick or dead of the disease, and inoculate this into a susceptible animal, the general symptoms and results produced are practically the same as in an ordinary case of the disease. This goes to prove that the products of pathogenic bacteria are toxic in character and harmful to the tissues, either locally or generally; that each of these toxic products gives rise in susceptible animals to characteristic symptoms which, taken together, indicate a specific disease, and that infection must be accordingly a chemical and toxicological process. Another point to note just here is that these toxins are apparently harmful to the bacteria themselves whenever they exceed a certain amount, as is shown by the fact that most of the infectious diseases are self-limiting, and by the cessation of growth and even the death of the germs in the various culture-media after a certain length of time. It is but fair to state, however, that there is another possible explanation of this latter phenomenon, viz., an increase in the resistance of the infected body to the action of the germs and toxins, or, as in the case of culture-media, the marked change in reaction caused by the bacterial products.

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[1] Abbott, loc. cit.

**Immunity.**—Having thus obtained some knowledge of the exciting causes of infectious diseases and of how they act, one of the most important considerations is in relation to the prevention of the incurrence of these diseases by the well, and to the antagonizing or checking of the further action of the cause in those already infected. It is well to disinfect and to destroy disease germs whenever and wherever it is possible to do so, and at the same time to prevent in any manner their transferrence from unknown or inaccessible sources to susceptible persons, but it is still better so to strengthen and fortify the human body that the microbes, even though received into it, will be unable to do it harm. Naturally our first desire would be to secure a permanent insusceptibility, if this might be had without too great risk or discomfort; but since this is rarely possible with our present knowledge, we must endeavor, especially when the danger of infection is imminent, to secure the greatest possible immunity even though that may be only temporary or incomplete. Occasionally we find individuals that possess extreme natural immunity to certain maladies; observation shows that most well persons have protection in the case of ordinary exposure to infec- s matter; and further investigation teaches that this protection is materially affected by such factors as one's state of health, occupation, age, or diet, or by injuries, drugs, fatigue, exposure to heat or cold, etc. But our desire is to know how to provide a positive immunity against each infection and for all persons. That we have the means of producing such protection in the case of one disease, at least, is well shown by the history of vaccination, and the work of many investigators in recent years indicates that the promise of similar results in regard to many other maladies is by no means vain. Certain it is that many human beings and animals have been rendered apparently immune to other fatal diseases, and the indications point to the probability that the human race will shortly have the same protection against most of the transmissible maladies that it now has against smallpox.

With the knowledge that immunity to infectious diseases may be produced either accidentally or intentionally, and may be practically applied without a complete understanding thereof, we need not consider the method whereby the body brings about such immunity. Nevertheless, it may be well to consider several theories that have been advanced in the attempt to explain the phenomenon. Of these, two have been practically disproved, viz., the *exhaustion* theory of Pasteur, which was that the pathogenic germs in their process of growth in the body removed some material from the latter necessary to their existence; and the diametrically opposite *retention* theory of Chauveau, which was that the germs produced some substance which gave immunity as long as it was retained in the tissues. On the other hand, there are strong adherents to both the *phagocytosis* theory of Metchnikoff and the *humoral* theory of Büchner.

The phagocytosis theory is, "that immunity against infection is essentially a matter between the invading bacteria on the one hand and the leucocytes of the tissues on the other; that during the first attack of the disease the white blood-corpuscles gain a tolerance to the poisons of the bacteria, and so are able to resist the next incursions of the enemy and actually to attack and destroy the latter." Büchner has apparently shown that the blood-plasma, especially that of immune animals, is bactericidal to many virulent germs, and he attributes this effect to the presence in the fluid of certain proteid substances akin to globulin. These he terms *alexins*, from a Greek word meaning to protect. Further, he believes that they act chemically in causing death of the disease germs, and that the increased amount of alexins in the blood of those who have acquired immunity is brought about by a stimulation or "reactive change" in certain cells due to the presence of the bacteria or their products. Moreover, this humoral theory serves to account for the natural immunity possessed by some individuals and animals, their body-juices presumably containing, through some cause or other, an extra quantity of the protective proteids.

But an essential factor in securing immunity is the power of the body to resist or endure the poisons produced by the disease germs, something fully as important as its ability to destroy the infecting organisms. Consequently there is another theory—that of the *antitoxins*—which, in view of recent developments and the fact that it is the most capable of immediate practical application, is probably the most important of all. It is well known that the human system has the power of tolerating or accommodating itself to the action of almost any toxic substance—provided the latter be administered first in sufficiently minute doses and then gradually increased—until it can in time withstand quantities that would quickly prove fatal to one unaccustomed to the poison. Ehrlich has further shown that with the toxic alkaloids of certain higher plants, after a certain degree of tolerance is attained the administration of the drug may be much more rapidly increased, and that while up to this point no apparent change occurs in the body-fluids, now, when the tolerance becomes so much increased, a new substance is produced in the blood which is capable of neutralizing the poison in not only the person or animal under experimentation, but also in others into whom it may be introduced. Further investigations have shown that this same production of antidotal or antagonizing substances may be brought about by the slow administration of the toxins of pathogenic bacteria—something not hard to understand when we remember that the bacterial toxins are just as much the products of plant-life as are the alkaloids that Ehrlich used, and very much like the latter in composition. "Antitoxin is thus chiefly known to us as a specific disease-resisting constituent of the serum of immunized animals."

On the other hand, the antitoxins, as these substances antidotal to the toxins are called, have been found to be albuminoid in character and similar in composition to the nucleins. In fact, attempts have been made to employ the latter in place of or in conjunction with the antitoxins, with results that have not been altogether without success.

Much credit must be given to the labors of Behring, Roux, Kitasato, Haffkine, and others for the development of practical methods of using the antitoxins, methods which are now recognized as eminently proper and even superior to any others in the treatment of some of the most virulent diseases. The great reduction in the mortality from one disease alone—diphtheria—already attained through the application of this treatment almost exceeds expectation and belief, and the promise seems now to be that the results with respect to cholera and other deadly maladies will be equally brilliant and add further glory to this new science of bacteriology.

To some it may seem that either the humoral or the antitoxin theory is identical with the discarded retention theory of Chauveau; but it should be noted that according to the latter the invading microbes themselves produce the antidote or antagonizing substance, while Büchner's theory attributes this production to the integral cells of the body, which furnish the alexins normally in minute quantities to the blood, and asserts that the latter are germicidal to the bacteria themselves; and, on the other hand, the antitoxins, though produced like the alexins by body-cells, act chemically in neutralizing the bacterial poisons, and are dependent upon the prior presence in the body of the toxins, being a result of its acquired tolerance to the latter. With alexins or antitoxins it is evident that the immunity will last only so long as these substances remain unchanged in the blood.

However, there is no reason why the phagocytosis, humoral, and antitoxin theories should not mutually support rather than tend to discredit one another. There seems to be good evidence of the phenomena upon which each of the three is based, and even with our present incomplete knowledge of the blood and its component parts, it is not difficult to conceive that while the alexins, and later the antitoxins, protect the leucocytes by respectively weakening the vitality of the microbes and neutralizing their products, the leucocytes thus guarded and in full vigor attack and make way with the bacteria, which have lost their power for evil. In other words, if the production of the toxins of an infectious malady is not too rapid, all three of these agents may combine to overcome the enemy, and not only to limit the disease, but also to give subsequent immunity for a more or less prolonged period.

Much consideration has lately been given to the so-called *lateral chain theory of immunity* suggested by Ehrlich in 1897, since it serves better than anything else to aid in the solution of many of the problems of this abstruse subject. It is primarily dependent upon the well-known fact that many poisons, including the bacterial and similar toxins, have a specific attraction toward and action upon certain cells of the body. Ehrlich assumes an extremely complicated cell protoplasm with many affinities for combination with external substances. These affinities may be hypothetically and graphically represented as slight protoplasmic protrusions on the contour of the cell-wall, and these affinities thus materialized he terms "lateral chains" or *receptors.* Now according to their particular and respective affinities the receptors attract to themselves the various molecular food particles that the cell needs, it being possible, however, for one receptor to have an affinity for several kinds of molecules. Such molecules capable of attraction and attachment to the receptors are termed "haptophores." Accordingly, haptophores of a poisonous nature that have either entered or been created in the body may become attached to certain receptors of a given cell, and if of sufficient number and virulence may altogether check the nutrition of and destroy the cell; but if not sufficient in number and toxicity, the harmful haptophores only stimulate the cell protoplasm to the formation of many new receptors of that particular kind in order that its nutrition may be maintained; and it is conceivable that through continued or repeated irritation the cell may create many more receptors than it needs, which may subsequently be separated from it and thrown off as particulate bits of protoplasm, each with its own specific affinities, into the surrounding fluids and spaces of the body. Eventually, then, there may be prepared enough specific receptors, either attached to or dissociated from the cells, to attract and unite with all the toxic haptophores present, so that the cells are no longer unduly irritated, but perform their functions in a normal manner. So also, cells primarily lacking the appropriate receptors are immune against the molecules of a given poison.

Ehrlich's theory goes further, and, taking into consideration the known production by the animal body under stimulation of particular foreign and harmful cells, such as bacteria, of specific substances capable of dissolving and destroying the invading cells, assumes the production of *amboceptors* that will bring into contact and union the solvent or *lysin* and the particular cells which it is to destroy.

Thus we can appreciate the identity of the receptors and antitoxins, and that the lysins just mentioned correspond to the alexins of Büchner.

"Acquired immunity depends upon the regeneration of receptors to compensate for those thrown out of service by union with useless haptophores. The increasing immunity characterizing immunization depends upon the regeneration of an unlimited number of receptors, so that the cell an provide for the ever-increasing number of haptophores ought to it and still have enough receptors remaining carry on its own nutrition."[1]

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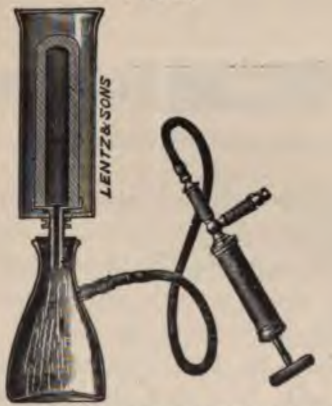
[1] Medicine, June, 1903, p. 450.

**Method of Preparing Diphtheria Antitoxin.**—Within a comparatively short space of time the antitoxins have been discovered, tried, and practically adopted by the medical profession of the civilized world as a safe and efficient means for the prevention or the alleviation and cure of several of our most dreaded diseases. A short account of the usual method of preparing the antitoxin of diphtheria will, therefore, probably not be uninteresting.

In the first place, it is necessary that the toxin of the disease should be produced, which is commonly done by growing the specific organism in peptone-bouillon. When this has attained a powerful and definite virulence, as determined by its effect on small animals of known weight, the organisms are destroyed by some germicide, such as trikresol, or more commonly are removed by careful filtration from the bouillon which holds the toxin in solution. A small quantity, say 1 c.c., of the

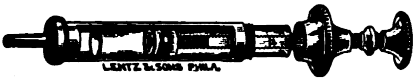
FIG. 10.



Filter for removing bacteria from fluid culture-media.

filtered bouillon is then injected into a large animal, such as the horse, which should be in good health, and preferably should have been tested previously by inoculations of tuberculin and mallein to eliminate the possibility of the presence of tuberculosis or glanders. The animal manifests for a few days the disturbances peculiar to the disease in question but usually in a minor degree, since the dose was purposely quite small in proportion to its weight; as soon as recovery is evident another inoculation of an increased dose is made, and so on until experiment shows that the animal can withstand practically an unlimited quantity of the toxic bouillon, and certainly an amount which would have been quickly fatal before the first inoculation. This is evidence that the antitoxin has been produced and that it exists in approximately sufficient degree in the blood-serum. A quantity of blood is then drawn with the strictest antiseptic precautions into sterile flasks from the jugular or other large vein of the animal, the latter returned to its quarters, and the blood set aside in a cool place to coagulate. This done, the clear serum containing the antitoxin is drawn off and to it is added a small quantity of trikresol or other harmless preservative.

FIG. 11.



Roux aseptic hypodermic syringe for administering antitoxin.

It is now necessary to determine the strength of the serum. The fatal dose of toxin for guinea-pigs is readily found by experiment. Behring therefore suggested in the case of diphtheria antitoxin that the immunizing unit be taken to be 1 c.c. of a serum of which 0.1 c.c. would prevent œdema and death in guinea-pigs when injected simultaneously with 10 times the fatal dose of the toxin. In other words, the immunizing unit was to be sufficient to overcome 100 times the amount of the toxin required to kill a guinea-pig.

The antitoxin serums now administered are, however, much stronger than this normal serum of Behring's, 10 c.c., the amount usually injected, being equivalent to from 600 to 2500 or even more immunizing units, the weaker strength being used for immunizing those who have not as yet incurred the disease. Much depends upon the early use of the specific antitoxin in cases of diphtheria, and probably also in the other diseases for which this method of treatment will be found valuable. It is not to be supposed that the remedy has any power to repair the organic lesions which have been caused by the action of the powerful toxins. That the antitoxin treatment is invaluable cannot be doubted. The statistics of Prof. Welch, of Johns Hopkins Hospital, founded on a very large number of diphtheria cases, "show an apparent reduction of case-mortality of 55.8 per cent.," and where the application was made in the first three days of the disease the mortality was only 8.5 per cent. in over 1100 cases as against a mortality of 30 per cent. or higher under former methods of treatment. Another interesting report is that of the Chicago Department of Health for 1896. In that city in that year there were 2436 cases of true diphtheria verified bacteriologically. The antitoxin was administered to 2302 of these, with a resultant mortality of only 6.56 per cent., or 151 deaths. Moreover, 2016 other persons exposed to the disease were inoculated with the antitoxin in order to immunize them, and of these, only 14 subsequently contracted the malady, and none died. Further comment seems unnecessary, but the statistics of the United States Census already quoted, showing a reduction of practically one-half in the death-rate from this disease in the last decade, viz., from 70.1 to 35.4 per 100,000 in over one-third the population of the whole country, is even more striking, especially as the gain must be attributed almost entirely to the adoption and use of the antitoxin. The results have been so positive, the advance so progressive, and any changes in the previous methods of treatment of the disease so slight as to preclude the possibility of doubt as to the wisdom of employing it both as a remedy and as a prophylactic.

The immunity secured by the use of an antitoxin is almost immediate, an advantage often of the greatest importance; but since it is passive, the antitoxin having been developed outside of the person protected, it is more or less transient, and the inoculation must be repeated at intervals, or when danger of new infection is imminent. The same remarks apply to the use of *antimicrobin*, the product resulting from the gradual introduction of the bodies of the bacteria rather than their toxins into susceptible and suitable animals. This gives rather a bacteriolytic form of immunity, and thus far is not so satisfactory as that due to antitoxin.

On the other hand, immunity that is acquired actively, either by accident or by deliberate experiment, is slower in developing, but much more likely to be permanent. It is a result, as we know, of most of the spontaneous infectious diseases, though its duration in some cases is briefer than we desire. It may also be secured by *prophylactic infection* or by *prophylactic intoxication*. In the former we may use virulent infective matter in much reduced doses or quantities, if possible; or better and more safely as far as man is concerned, some form of attenuated virus may be employed, the infecting matter having been modified by development in animals of another species, by heat, light, drying, electricity, growth in unfavorable media, etc. As an illustration, we have the modern vaccine virus derived from the cow which has entirely supplanted the former direct inoculation of matter from the human patient. As for prophylactic intoxication, we may use either the dead bodies of the infectious bacteria, as has been done by Haffkine in his work against plague and cholera, or the products of the organisms derived from artificial cultures, as indicated in describing the production of antitoxin. Various factors, some still unsettled, must determine the advisability of the use in a given case of one or another of the above methods; but it must be remembered in regard to actively acquired immunity, that not only is it at times too slow in development to be of value after infection has occurred, but also that "the introduction of toxins or bacterial proteids after the onset of the disease may be not merely useless, but actually harmful by adding to the sum total of toxic material against which the tissues struggle."

Nevertheless, experience will continue to show that whether one or all of these methods of securing immunity may be employed or whether others by which the body protects itself may be discovered, sanitation and a condition of perfect health throughout the system are of the utmost importance in warding off attacks of or securing immunity from any of the pathogenic organisms, and in withstanding their ravages should disease be incurred. A sound body therefore is a most vitally active and not simply a passive agent for the prevention of such diseases.

# CHAPTER III.

## THE ATMOSPHERE—AIR.

THE composition of the atmosphere surrounding the earth is remarkably uniform. It is practically always the same everywhere provided no obstacle be interposed to the action of those natural forces by which this uniformity is maintained. This atmosphere is estimated to be about forty miles in depth, and its weight-pressure, of which we have a visible manifestation in the action of the barometer, upon the total surface of the adult human body is equivalent to that of about fourteen tons. Any considerable variation in this pressure may give rise to disturbances of health more or less serious, such as the cardiac derangements and "mountain sickness" experienced by strangers visiting high altitudes, or the "caisson disease" of those who work in a compressed atmosphere. In fact, it is not improbable that some of the vague disturbances of comfort to which a large class of persons are subject during changes of the weather will hereafter be found to be due to the variations in this pressure which are constantly occurring everywhere.

The average composition of the air in its normal state is about as follows: oxygen, 20.96 per cent. by volume; nitrogen and argon, 79 per cent.; carbon dioxide, 0.04 per cent.; aqueous vapor, varying in amount with the temperature and other conditions; a trace of ammonia, and a variable amount of ozone, organic matter, sodium salts, etc.

The variation in the percentage of oxygen may be from 20.87 in towns to 20.98 in pure mountain air or far out at sea; in the percentage of carbon dioxide, from 0.05 to 0.02. So far as we know at present, the nitrogen variation is almost infinitesimal. The air is a mechanical, not a chemical mixture, and there is always some change taking place in the proportions of the various constituents. However, the mixture is maintained in its wonderful uniformity by the interdependent action of plants and animals, and by the diffusion of gases, the law of which is that "a gas expands into a space in which there is another gas as freely and as rapidly as if there were a vacuum." Though this agency, like the other, is continually operating, its results are greatly facilitated by adventitious air-currents and by the application of heat. When a gas is thus diffused, it will not separate again from the others under ordinary circumstances.

Oxygen is the most important of the above constituents. It supports all animal life; oxidizes, destroys, and renders harmless organic impurities, and by oxygenating the blood and oxidizing the food for our tissues gives heat and energy, the vital source of all our thoughts and actions. The supply to the atmosphere is constantly maintained by the higher plant-life, which decomposes carbon dioxide and gives off oxygen to the air. In man the greatest limit of life without oxygen or air is about four minutes. A decrease in the proportion of oxygen in the air does not manifest itself by untoward symptoms until there is less than 13 per cent. by volume; then as it falls lower and lower the respirations become slower, deeper, and more difficult, less oxygen is absorbed by the blood, and there follow dyspnœa, asphyxia, and death. This may occur within a short time when the percentage goes below

8 per cent., and fatal asphyxia supervenes very rapidly when there is as little as 3 per cent. of oxygen.

The main function of the nitrogen of the atmosphere seems to be to act as a diluent and to prevent the too energetic action of the oxygen. We know now, however, that by the aid of certain bacteria at least one family of plants—the leguminosæ—is able to take nitrogen almost directly from the air and to store it for animal use in the form of proteids. The ammonia ever present in the air is also a source of nitrogen food for some plants.

The gaseous element *argon*, recently discovered by Lord Rayleigh and Prof. Ramsay, comprises about 1 per cent. of what has heretofore been considered atmospheric nitrogen. Thus far little is known concerning it except that its atomic weight is probably somewhat less than 40, its density about 20, and that it is very inert, though Berthelot has succeeded in making it combine with nascent vapors of benzene under the influence of an electrical discharge. That it is a constant component of the atmosphere for some definite purpose is more than probable, but what this purpose may be is as yet unknown.

The carbon dioxide[1] present in the atmosphere is of no direct use to animals, but is essential to the support of vegetable life, furnishing part of the carbon necessary for the formation of the carbohydrates and proteids, which are, next to water, the main constituents of plants. The proportion of carbon dioxide in the out-door air varies somewhat from time to time, owing to the changing conditions. It is washed out of the air by rain, and there is therefore less after a heavy storm; plants absorb it by day, and some give off a slight quantity by night; the strata of the atmosphere near the ground receive an excess of it from the soil-air; it is a constant product of combustion and of the decomposition of organic matter by saprophytic bacteria, etc. Though heavier than air, it is comparatively evenly distributed through the atmosphere by the force of diffusion.

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[1] Carbon dioxide = carbonic acid gas = carbonic anhydride = $CO_2$. Carbon monoxide = carbonous oxide = CO.

The normal proportion in the atmosphere varies from 0.02 per cent. to 0.05 per cent., but we may take the average to be about 0.04 per cent. Should, however, any important tests of the amount in-doors be required, the percentage in the out-door air at that particular time and place should also be determined for the sake of accuracy. Within the limits just given the carbon dioxide cannot be considered as an impurity of the atmosphere, for it is ever present in the air, and is as necessary to plant-life as oxygen is to animals. It is derived from the combustion of carbonaceous materials, from the exhalations and excretions of animals and men, and, as was indicated, in large measure from the action of the saprophytic bacteria and also of the budding fungi upon organic matter. Moreover, any excess above the normal percentage as given is to be regarded not so much as an impurity as an indication that certain processes are at work, which by their other products, may make the air impure and unsafe for human use.

The amount of aqueous vapor in the atmosphere varies from time to time because the factors governing it—condensation and evaporation—are continuously in action, these depending, of course, mainly upon the continual variations in temperature. There is probably never a perfectly dry air unless it is made so artificially, and precipitation occurs the moment complete saturation is reached. The range of relative humidity is probably from 30 to 100 per cent., this being equivalent, according to the temperature, to a water-content of from 1 to 12 or 14 grains to the cubic foot of air. The most satisfactory proportion for health has not been experimentally determined, but is generally considered to be from 65 to 75 per cent. when the temperature is moderate.[1]

In the out-door air there is at least a trace of ammonia either free or combined, a small amount of the salts of sodium (especially near the sea) and of other metals, and a trace of organic matter. This last is part of the animal and vegetable débris of the earth; when above a trace, it is to be treated as an impurity, as should any excess of ammonia.

Minute particles of innumerable substances are being constantly thrown off into the atmosphere, and it is only the unceasing action of nature's purifying powers that keeps the proportion within the limits of safety to the human race. Solid particles, lifted up by the winds, fall to the earth again, or, if organic, are partially oxidized and decomposed by the oxygen and ozone. The gases are diluted and diffused so as to be no longer harmful, or are decomposed, or are washed back to the earth by rain or snow. The great volume of carbon dioxide is kept within bounds by the action of the vegetable world. The natural purifiers of the atmosphere, therefore, are the force of gravity, diffusion, dilution by the air itself, winds, oxidation, rain, and the action of plant-life; and so exactly are these adjusted to their work that never, when they have fair opportunity to act, does the composition of the air vary much from the normal for any great length of time.

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[1] When the temperature is upward of 80° F. a humidity of but little over 70 per cent. may be very uncomfortable and depressing if the air is still and evaporation from the body surface thus impeded. A breeze makes even a higher humidity less noticeable.

The impurities in the atmosphere that are especially liable to have a deleterious influence upon health may be classed as follows: 1. Suspended matters. 2. Gaseous and semi-gaseous substances, including: 3. Those especially due to respiratory, combustion, and decomposition processes, and which are particularly liable to contaminate the air of dwellings or inhabited apartments.

The most important suspended matters are sand, dust, soot, pollen of various plants, micro-organisms of all kinds, particles of epithelia and other excreta thrown off from animal bodies, and finely divided substances characteristic of certain trades or industries. These may do harm by clogging the air-vesicles of the lungs and thus obstructing respiration, though it is doubtful whether their action is ever only so mild or simple; by their irritant action upon the respiratory passages; by being in themselves poisonous or hostile to the system, or as in the case of micro-organisms by the influence they have in the causation of disease. Disease germs may lodge in the respiratory passages and do harm, or may be swallowed and so cause maladies, such as typhoid fever or cholera, which primarily affect the digestive tract.

It is, however, questionable whether pathogenic organisms, especially the bacteria, are commonly to be found dissociated from other substances floating in the air. Experiments by Cornet and others seem to show that such microbes are more apt to be adherent to dust particles, particularly those of organic nature, and it is probable that free bacteria in the out-door atmosphere could not long maintain their vitality deprived of nutriment and exposed to the action of light and oxygen. Besides, they are so quickly reduced in numbers in proportion to any considerable volume of air that the occasions must be rare indeed when they could thus cause disease. In-doors, especially where ventilation is neglected, the case is different, and there is no doubt that the air frequently becomes the carrier of dangerous pathogens.

We must also make a distinction as to whether the other solid impurities are found in the out-door air or in enclosed spaces; and if in the latter, whether in healthful dwellings, in sick-rooms and hospitals, or in workshops and factories. Out-of-doors, dust, sand, soot, pollen, waste dirt from dwellings, street refuse, and the remains of plant and animal life will predominate; in-doors the particles will be more limited in variety, but not in importance. Among them will be epithelial and other cells, possibly pus-corpuscles, hair, bits of clothing, food, etc. One may also find arsenical or other poisonous dust from wall-paper or paint. In sick-rooms and hospitals there will probably be pus-cells, mycelia, bacteria, etc. Mills, factories, and mines have their special atmospheres laden with particles peculiar to the occupation, which in many cases have a marked effect for harm on the health of the workers.

The gaseous and semi-gaseous impurities of most importance are those resulting from human respiration and cutaneous exhalations, products of combustion, peculiar gases in sewer-air or soil-air, organic emanations and vapors from decomposing animal and vegetable matter, and the volatile substances that characterize the various atmospheres in and about gas-works, factories, and other places of various industries. Chemically, they may be classified as the various compounds of carbon and of sulphur with oxygen and hydrogen, and as ammonia compounds, volatilized minerals and mineral acids, and many gaseous and semi-gaseous matters of organic nature but indeterminate composition.

Inasmuch as certain of these impurities, viz., human exhalations, combustion-products, and not infrequently the so-called sewer-gas, are particularly liable to be found together as contaminants of the atmosphere of inhabited rooms and dwellings, it will be advisable to consider them in a class by themselves, and to study their effect upon health both collectively and singly.

The volatile excreta from the lungs and skin are carbon dioxide, aqueous vapor, and a considerable amount of nitrogenous organic matter, to which the term "crowd-poison" is sometimes given. As products of combustion from the ordinary lighting and heating apparatus of dwellings we may have carbon dioxide, carbon monoxide, sulphur dioxide, ammonia (with possibly its sulphide), and aqueous vapor. Of sewer-gas and soil-air we shall speak later.

Carbon dioxide, contrary to the general opinion, cannot be said to be directly harmful to health in the proportions in which it is likely to be found in any dwelling or inhabited apartment. Although present to the extent of not more than 0.05 per cent. in normal out-door air, numerous experiments indicate that both men and animals may inhale much larger proportions than this without apparent harm provided the percentage of oxygen in the air be maintained at or above the normal; an increase of the carbon dioxide from other sources than respiration and combustion seems to have no appreciable effect upon the system until it reaches more than 2 per cent., and men work daily in atmospheres containing almost this amount as a result of their peculiar occupations. Dyspnœa does not begin to occur, and then only in some, until the percentage goes above 3 or 4. In quantities above these figures there is much difference of opinion as to the effect of the gas upon the human economy, and the writer is not aware that it has ever been determined just what percentage is fatal. Parkes states the lethal proportion to be from 5 to 10 per cent.; while another authority states that animals may be kept for a long time in an atmosphere in which there is a high percentage of carbon dioxide provided the percentage of oxygen be increased at the same time. Hime says that "it may be assumed that 10 or 20 per per cent. is a dangerous amount";[1] but Wilson[2] shows that air having from 25 to 30 per cent. may be inhaled with impunity. It is to be understood that the above percentages are all *by volume*.

According to his weight, an adult man at rest absorbs from 15 to 18 cubic feet of oxygen and exhales from 12 to 14 cubic feet of carbon dioxide in twenty-four hours. Reichert[3] says: "The amount of O varies from 600 to 1200 grammes (15 to 30 cubic feet) per diem, and that of $CO_2$ from 700 to 1400 grammes (12.5 to 25 cubic feet)—approximate averages being about 750 grammes of O and 875 grammes of $CO_2$." The minimum excretion may therefore fairly be taken to be about 0.7 cubic foot of carbon dioxide for adult men and 0.6 cubic foot for women, or for each person of a mixed assemblage. Now it is evident that it would require many hours before a room of, say, 1000 cubic feet capacity would lose sufficient oxygen or gain sufficient carbon dioxide owing to the presence in it of a single adult occupant to produce even the slightest apparent harmful results, even though ingress of fresh air were prevented; and yet experience tells us that the atmosphere of such a room will become exceedingly foul and actually detrimental to health long before the lapse of time necessary to exhale sufficient carbon dioxide to induce serious effects. Moreover, carbon dioxide is odorless, while the air of inhabited, unventilated rooms is characterized by a decidedly offensive smell that remains for some time even after adequate ventilation has been secured and when chemical tests show the percentage of carbon dioxide to have been reduced to nearly the normal. "The chemical analyses of the air of overcrowded rooms, and the experiments upon animals made by many investigators, indicate that the evil effects observed are probably not due to the comparatively small proportions of carbonic acid usually found under such circumstances. . . . The proportion of increase of $CO_2$ and of diminution of oxygen which has been found to exist in badly ventilated churches, schools, theatres, etc., is not sufficiently great to account satisfactorily for the great discomfort which such conditions produce in many persons, and there is no evidence that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death-rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms."[1] Therefore, it must be something other than carbon dioxide that dangerously pollutes the air of dwellings and necessitates the provision of some system of ventilation. However, with our present knowledge we cannot say that a diminution of oxygen and an increase of carbon dioxide in the atmosphere which one breathes habitually do not tend to lower the general tone and perhaps the bactericidal powers of the body, and thus to render it more susceptible to deleterious influences; and there is some evidence that as the carbon dioxide in the atmosphere increases there is a lessening of the amount of this gas excreted from the body; so that on general principles it will always be wiser to use every reasonable means to maintain the normal proportion of the various gases in the atmosphere. Moreover, the fact that tuberculous patients usually improve if they live continuously out of doors would indicate that the full quota of oxygen in the air is essential to the best interests of health.

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[1] Stevenson and Murphy, vol. i., p. 945.

[2] American Journal of Pharmacy, 1893, p. 561.

[3] American Text-book of Physiology, p. 536.

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[1] "The Composition of Expired Air and its Effect upon Animal Life." Mitchell, Billings, and Bergey, No. 989, vol. xxix., Smithsonian Contributions to Knowledge.

Aqueous vapor is another of the substances excreted continually from both the lungs and the skin; but it is obvious that in itself it cannot be directly harmful to the system, for we find it ever present in all natural atmospheres, and are continually replacing by imbibition its loss from our bodies. The quantity daily thrown off from the lungs and skin will depend on the temperature and humidity of the atmosphere, the quantity of air inspired and water imbibed, and many other factors; but under rdinary conditions the average excretion will be from 00 to 1700 grammes (about 3.5 to 60 fluidounces), though ncreased exertion might cause even the latter amount to e greatly exceeded. It is accordingly possible that this arge quantity of moisture, tending to saturate an atmosphere already humid, might act indirectly upon the system by preventing evaporation from the skin, and thus reflexly checking the excretion of the waste matters by the sweat-glands, the retention of these wastes in the system probably helping to produce the depression, headache, and other symptoms experienced by those breathing foul air. It has been noticed that these symptoms due to foul air are more readily manifested when the temperature of the atmosphere is much below or much above the usual room-temperature of 65° to 70° F. At low temperatures the air is readily saturated, and beside, the excreting action of the skin is much lessened by the cold; at high temperatures the humidity is often already near the saturation-point, while the external heat tends to increase the quantity of water given off by the lungs and skin. "At high temperatures the respiratory centres are affected where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture—at low temperatures the consumption of oxygen increases and the demand for it becomes more urgent."[1] At 70° F. the aqueous exhalation from an adult body would in an hour or less completely saturate from 350 to 600 cubic feet of air having the not unusual relative humidity of 75 per cent., while at 80° F. an equal or even greater volume of air would doubtless gain its maximum of moisture from the increase of perspiration due to the extra heat. Moreover, as evaporation of the perspiration is one of the most important means for maintaining the balance between heat-production and heat-dissipation, interference with this process naturally tends to raise rapidly the body-temperature and produce the consequent effects upon its nervous mechanism.

The third contaminant given to the air from human bodies is an indefinite volume of offensive organic matter, and for a time this has been looked upon as by far the most harmful part of animal exhalations. But recently experiments by various investigators have seemed to indicate that this organic effluvium is not so dangerous as it has hitherto been considered, and that part at least of the symptoms due to air vitiated by respiration is to be attributed to the conditions already mentioned, viz., a decrease of oxygen and an increase of carbon dioxide, heat, and moisture. It is also doubtful whether much, if any, of this organic matter comes from the *lungs* of healthy persons. "In ordinary quiet respiration no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. . . . The cause of unpleasant, musty odors in rooms may in part be due to volatile products of decomposition from decayed teeth, foul mouths, or disorders of the digestive apparatus, and in part to volatile fatty acids given off with or produced from the excretions of the skin, and from clothing soiled with such excretions."[1] However, whatever may be the exact source of this contamination, we know this concerning it—that it is decidedly offensive to the sense of smell, that it is organic and nitrogenous, yielding ammonia, darkening sulphuric acid, decolorizing potassium permanganate, and rendering offensive pure water through which the vitiated air has been drawn. Moreover, it must in fairness be stated that in spite of the later experiments it has seemed to such careful investigators as Brown-Séquard, d'Arsonval, Merkel, and others to be directly poisonous to lower animals. In general, it is given off proportionately with the carbon dioxide from the body, though this rule is not infallible; it is apt to be unevenly distributed throughout the atmosphere of the apartment, and is probably therefore not truly gaseous, but more like an impalpable dust; it oxidizes but slowly, being evident for some time after fresh air has been admitted and the carbon dioxide has been reduced almost to the normal, and, while neither condensed nor dissolved in the aqueous vapor from the body, it is especially attracted and retained by hygroscopic substances such as wool, paper, feathers, etc. Its smell is generally perceptible when the respiratory carbon dioxide reaches 0.03 or 0.04 per cent., sometimes before this point is reached, especially in sick-rooms or hospital wards, and is decidedly offensive when the total carbon dioxide approaches 0.1 per cent.

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[1] Mitchell, Billings, and Bergey, loc. cit.

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[1] Mitchell, Billings, and Bergey, loc. cit.

The most important of the impurities resulting from the combustion of coal, the principal fuel substance used in towns and cities, are soot and tarry matters (to the extent of about 1 per cent. of the coal consumed), carbon monoxide and dioxide, aqueous vapor, and more or less ammonium sulphide, carbon disulphide, hydrogen sulphide, sulphur, sulphur dioxide, and sulphuric acid. The relative amounts of the oxides of carbon—as well as of the other gases—will depend upon the perfection of combustion; "but it has been calculated that for every ton of coal burnt in London something like three tons of carbon dioxide are produced," and as the coal consumption of that city is over 30,000 tons per diem, we can readily see that its atmosphere must receive the enormous daily contamination of about 300 tons of soot and 90,000 tons of carbonic acid. No wonder they have an *occasional* fog there!

The combustion-products of wood are in the main carbon monoxide and dioxide, and water, while those of coke and of gas are practically the same as those of coal. From the heating apparatus, if properly constructed and arranged, these products pass almost directly to the exterior of dwellings and are rapidly dissipated in spite of their excessive volume, for "diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide," and in fact from the other combustion-products also, with the exception of the soot and tarry products.

Should, however, combustion be incomplete, or should the stoves or other heating apparatus be imperfect, the gases may seriously or even dangerously contaminate the house-air, the deadly carbon monoxide being particularly liable to leak not only through the crevices, but actually through the heated cast-iron plates, etc., of stoves and furnaces. Théoretically, a pound of coal requires 160 cubic feet of air for its perfect combustion, but actually from one-half to as much more must be supplied to the ordinary heating apparatus to secure complete oxidation of the fuel.

Practically all the devices for artificial illumination, with the exception of the incandescent electric light, give off directly to the surrounding air combustion-products which are much the same as those from coal, and this contamination is consequently a positive factor in the vitiation of in-door air. "Every cubic foot of coal-gas yields, on combustion, roughly, half its own volume, or 0.52 cubic foot, of carbon dioxide, and 1.34 cubic foot of water vapor," besides some little carbon monoxide when ordinary burners are used. "Speaking generally, it may be said that each cubic foot of gas burnt per hour from the ordinary burners vitiates as much air as would be rendered impure by the respiration of an individual; it at the same time will raise the temperature of 31,290 cubic feet of air 1 degree F., and yields 217 calories (a kilogramme of water heated 1 degree C.) or 860 British heat-units (a pound of water heated 1 degree F.)."[1]

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[1] Notter and Firth, Treatise on Hygiene, p. 140.

But inasmuch as the products of combustion are superheated, they rise at once to the top of the room and, for the most part, quickly escape to the outer air through the combined influence of negative gravity and diffusion; so that comparatively little air is needed to dilute the small proportion of such products that eventually cool and fall to the breathing-level.

The following table[1] shows the influence of various lighting agents with respect to the condition of the room-air:

| | Quantity consumed. | Candle-power. | Oxygen removed. | Carbon dioxide produced. | Moisture produced. | Heat calories produced. | Vitiation equal to adults. |
|---|---|---|---|---|---|---|---|
| | | | Cu. ft. | Cu. ft. | Cu. ft. | | |
| Tallow candles . . . . . . . . | 2200 grains | 16 | 10.7 | 7.3 | 8.2 | 1400 | 12.0 |
| Sperm candles . . . . . . . . | 1740 " | 16 | 9.6 | 6.5 | 6.5 | 1137 | 11.0 |
| Paraffin oil lamp . . . . . . . | 992 " | 16 | 6.2 | 4.5 | 3.5 | 1030 | 7.5 |
| Kerosene oil lamp . . . . . . | 909 " | 16 | 5.9 | 4.1 | 3.3 | 1030 | 7.0 |
| Coal-gas, No. 5 batwing burner . . . . . . . . . . | 5.5 cu. ft. | 16 | 6.5 | 2.8 | 7.3 | 1194 | 5.0 |
| Coal-gas, Argand burner . . . | 4.8 " | 16 | 5.8 | 2.6 | 6.4 | 1240 | 4.3 |
| Coal-gas, regeneration (Siemens) burner . . . . . . . | 3.2 " | 32 | 3.6 | 1.7 | 4.2 | 760 | 2.8 |
| Coal-gas (Welsbach incandescent) . . . . . . . . . . . | 3.5 " | 50 | 4.1 | 1.8 | 4.7 | 763 | 3.0 |
| Electric incandescent light . . | 0.3 lb. coal | 16 | 0.0 | 0.0 | 0.0 | 37 | 0.0 |

From this table it will be learned that the incandescent electric light is the most satisfactory from a hygienic point of view, and there is no doubt that its very general introduction has done much toward obviating a constant source of vitiation, especially in rooms which require much artificial light, and are at the same time difficult to ventilate. It is said that in a bank in London, in which several hundred persons are employed, the absences on account of illness have been so far reduced, apparently by the introduction of the incandescent electric light alone, that the extra labor gained has more than compensated for the increased cost of lighting. The electric arc light is said to form nitric acid; but even so, its effects are not so harmful as are those of the products of combustion of the ordinary candle, lamp, or gas-jet.

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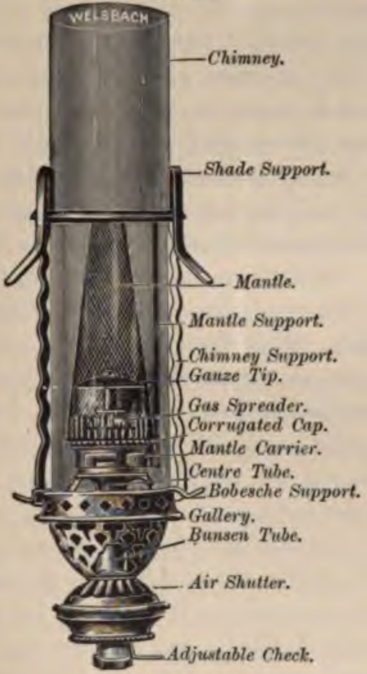
[1] Notter and Firth, Treatise on Hygiene, p. 141.

Next to the incandescent electric light in importance are the Welsbach and Siemens gas-lights; but of these the latter has not the illuminating power, nor is it so well adapted to house use as is the former. The Welsbach light makes use of the Bunsen flame (in which, by the way, the carbon of the gaseous fuel is completely consumed and converted into carbon dioxide) to render incandescent a non-combustible mantle or network, composed of vegetable fibre saturated with the oxides of certain metals which have the property of becoming intensely luminous when sufficiently heated. It gives a white light of great illuminating and considerable actinic power, and of practically unvarying intensity. In fact, this quality of steadiness, in which it surpasses even the incandescent electric light, is by no means the least of its hygienic advantages, since such steadiness is an important factor in the conservation of the eyesight.

Recently hydrocarbon (gasoline) lamps, making use of an incandescent mantle similar to the Welsbach, have been placed on the market, and are said to be safe and free from odor or danger of explosion. If these claims can be sustained, such lamps are of value, since they furnish a powerful and steady incandescent light at very low cost.

A comparatively new illuminant, not mentioned in the foregoing table, is acetylene gas. This gives a very white and powerfully actinic light, and, on account of ease of production and the small amount needed for ordinary lighting, is cheap and does not greatly vitiate the atmosphere. But a mixture with air in proportions of from 4 to 25 per cent. is highly explosive, and consequently the gas is not yet much used for interior lighting.

FIG. 12.



Welsbach light.

**Sewer-gas and Soil-air.**—What is commonly called sewer-gas is a mixture of a number of gases, such as carbon dioxide, carburetted hydrogen, ammonium and hydrogen sulphide, nitrogen, etc., together with a considerable amount of fetid organic matters, the volatile or semi-volatile products of animal and vegetable decomposition, varying according to the condition of the sewer, the kind of matter received therein, the amount of surface-water, etc. The air from a closed cesspool may be extremely foul and poisonous, so much so that the emanations have not infrequently caused death in those who inhaled them in full concentration; on the other hand, the atmosphere of a properly constructed and well-flushed sewer may be almost as pure as that above the surface of the ground. Bacteria are present in varying numbers, with the possibility of some of them being the germs of specific diseases. But fresh sewage is not so likely to contaminate the air above it with microbes as that in which decomposition has begun, since Frankland has shown that solid or liquid particles are not liable to be scattered into the air by any disturbance to which the sewage may be subjected until gases of decomposition are produced. According to some writers, the bursting of bubbles of gas on the surface may discharge the bacteria into the sewer-air. It has also been shown that "bacteria can undoubtedly grow up the sides or walls of damp, nutrient sewers, and if these latter become at all dry, air currents readily detach and disperse them." It is, however, questionable whether many disease germs can withstand the natural antagonism of the saprophytic bacteria that predominate in sewage and on sewer walls.

Another class of impurities that may at times be found in the air of dwellings comprises those coming from the soil and soil-air. The *soil*, in hygiene, refers to all that portion of the earth's crust that can in any way affect the health. All soils contain more or less air—soft sandstones from 20 to 40 per cent., loose sands from 40 to 50 per cent., and loose soils often very much more.

As the soil is the recipient of most of the solid and liquid waste of all animal and vegetable life, and as the myriads of saprophytic bacteria that inhabit its upper strata are constantly working to convert this dead organic matter into simpler compounds suited to the nourishment of plant-life, the soil-air, taking the atmosphere above as a standard, will usually be far from pure.[1] It is rich in carbon dioxide and in organic vapors and gases, while the proportion of oxygen is probably always less than that of the air above ground. Moreover, the carbon dioxide increases and the oxygen decreases the deeper below the surface the sample is taken. As much of the carbon dioxide is evidently derived from organic pollutions, it might be supposed that this gas could be taken as an index of the degree of the latter, and so it might if other conditions, such as permeability of soil, rate of circulation, etc., were always the same. But they are not, and the composition of the soil-air is practically not the same at any two places, nor for the same place at different times. The underground air is constantly in circulation, even to a considerable depth; but there is a hindrance to its free movement and diffusibility, and this, together with the great variation in the distribution of oxidizable and other contaminating matters, causes the variations in its composition. The carbon dioxide, therefore, cannot be taken as an index of the relative purity.

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[1] Too much importance cannot be attributed to this saprophytic action in the upper soil, for it is one of nature's wonderful methods of securing and conserving not only the purity of our environment, but also the perpetuation of organic life.

The forces that maintain the circulation of the ground-air are the wind, the daily change of surface temperature, the fall of rain, and especially in winter the local and artificial conditions of civilization. A very slight wind will drive air through the soil for long distances, the rise and fall of the ground-water has its obvious effect, and the movement due even to slight changes of temperature is likely to be quite extensive and positive.

Owing to evaporation from the ground-water, the soil-air is always quite humid, and, according to some writers, may also be laden with bacteria and other very light substances lifted up by the ascensional power of evaporation.

As sewage, house-wastes, and dirt of all kinds are particularly liable to contaminate the soil about any inhabited dwelling, the air of that soil will more than likely be very impure, and care must be taken that it is not drawn into the house. This is especially apt to happen in cold weather, when house-fires are lighted and the in-door air is thus made warmer than that without, the tendency then being for the soil-air to pass, if possible, through the cellar walls and floors. These should be made as nearly air-tight as possible, and special attention should be given to the space underneath and about the furnaces or basement heating apparatus. As an instance of the importance of these precautions, Hime[1] gives an account of the death of four persons. Enough illuminating- (coal-) gas was drawn from a broken pipe fifteen feet distant from the foundation walls of the dwelling to cause the fatality, although there were only eight or ten inches of tramped earth above the pipe and the only aspirating force was the difference of temperature within and without the house. A number of explosions have occurred due to a similar leakage of gas from street mains through basement walls or into drains and sewers, since the admixture of illuminating-gas with air forms a most powerful and dangerous explosive.

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[1] Stevenson and Murphy, Treatise on Hygiene, vol. i., p. 949.

There is no direct evidence that the emanations from bone-yards, soap-factories, garbage-incinerators, etc., are actually harmful to health ; but they may be very decided nuisances to those living near by, and all such places should be strictly controlled by the proper sanitary authorities.

The atmosphere of mines and other excavations is subject to contamination by the excess of carbon dioxide in the soil-air, by gases from blasting agents and from fissures in rock, and by the products of respiration from men and animals working in the mines, etc. The air in the holds of ships is also likely to be foul owing to the difficulty of changing it sufficiently often, and frequently also to the insanitary character of cargoes. In such situations proper ventilation should be secured by all means available, and special care taken that the impure air does not affect the laborers in the one case or the passengers and crew in the other.

**Diseases Caused by Impure Air.**—As a rule, the human system has the power of accommodating itself, through habit, to withstand influences which, in one unaccustomed to them, would soon produce serious results. But in spite of this, if the body be exposed for any considerable length of time to conditions of impurity or deterioration in its supply of air, water, or food, such conditions will always tend to undermine health and increase the susceptibility to disease, even though they cause no more serious results. "Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is most important. No one who has paid any attention to the condition of health and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences and sometimes even regulates the second. . . . The air may affect health by variations in the amount or conditions of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i. e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air, and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of food and air."[1]

The definite diseases caused by the solid impurities in the atmosphere are almost all such as affect the respiratory passages and organs, with the possible exception of those engendered by specific bacteria and other microbes. Much therefore depends upon the physical character of the solid impurities. Soft particles and those with edges smooth and rounded, like soot and coal-dust, may apparently do nothing more than coat or clog the air-vesicles and finer bronchial tubes, and in this way diminish the area of lung tissue exposed to the inspired air, although it is questionable whether any foreign matter in the lungs does not cause more or less irritation. With most of us, however, such impurities are of little account if care be taken to develop the full respiratory capacity of the chest; but where the air is heavily charged with such dust it has a positive effect upon health and duration of life. In 1862 Sir John Simon stated that with one exception "the 300,000 (coal) miners of England and Wales break down as a class prematurely from bronchitis and pneumonia, caused by the atmosphere in which they live. The exception is important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary diseases, or do so in a slight degree only." Happily, since this was written satisfactory ventilation systems have been placed in most of the collieries of England, and the condition of the laborers correspondingly improved; but coal-miners are still, as a class, particularly liable to bronchitis, pneumonia, asthma, emphysema, and fibrosis (fibroid phthisis), though they seem to be but slightly subject to primary tuberculosis of the lungs or other organs.

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[1] Stevenson and Murphy, vol. i., pp. 121 and 122.

On the other hand, if the particles of dust in the air are hard, angular, and sharp, the lung tissues are readily lacerated, inflammatory processes are quickly set up, and the opportunity for the inoculation of tubercle bacilli and other disease germs is very great. The mortality from tubercular phthisis among metal-miners, needle-cutters, steel-grinders and tool-grinders, cotton-spinners, etc., is remarkable, and they are also especially subject to asthma and emphysema. Among Cornish tin-miners, 68 per cent. of all sick are consumptive; of needle-makers, over 60 per cent.; of flint-cutters, glass-cutters and -polishers, and of grindstone-makers, from 80 to 90 per cent., etc. It is said that a mixture of mineral and metallic dust seems to be more harmful than metallic dust alone, perhaps because of the greater clogging of the air-vesicles by the mineral matter.

Likewise, with other occupations where there is much irritative dust floating in the air, the effect upon the health of the worker is marked, and we find lung troubles prevalent and many suffering and dying from phthisis, as, for instance, among cotton-spinners, flax-dressers, hemp-dressers, pottery-makers, etc. Defective ventilation, accumulations of noxious gases, improper habits, insufficient disinfection of sputa, and often the excessive humidity of the air necessary in some of these pursuits, have doubtless something to do with the high sick-rates and death-rates; but withal, the marked effect of the solid atmospheric impurities cannot be denied.

Again, workers in poisonous metals, compounds, or gases, such as paint-makers and painters, type-setters, gilders (using mercury), brass-founders, coppersmiths, etc., are subject to the influence of the respective poisons and the symptoms produced by them, with a correspondingly increased mortality.

Among the diseases that may be caused by the inhalation or swallowing of specific micro-organisms floating in the atmosphere are erysipelas, measles, scarlet fever, diphtheria, whooping-cough, infectious pneumonia, phthisis and other forms of tuberculosis, and very probably epidemic influenza; and although the germs of cholera and typhoid fever are usually carried by the drinking-water or food, they doubtless do sometimes find their way into the system from a contaminated atmosphere.[1] Malaria also is now practically proved to be due to a minute organism, which, though usually introduced into the human body in another way, may possibly be present in the air of malarial districts and be carried long distances thence by winds.

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[1] The report of the commission appointed to inquire into the prevalence and causes of typhoid fever in the late Spanish-American War shows

Lastly, the spores of certain fungi which have been found in the air of hospitals and elsewhere are known to cause skin diseases, such as the tineas and favus in men; and it is almost as certain that the irritating or poisonous pollen of certain grasses and other plants have much to do with the causation or aggravation of maladies such as hay-fever or rose-cold.

From what has been said, it will be surmised that it is scarcely possible at present to specify the exact effect upon the health of each of the impurities given to the air by the human body, and that the symptoms observed to be due to air thus vitiated are very probably an evidence and result of the combined action of these factors rather than of any one of them singly. However, the writer feels that the oppression so commonly experienced is often fairly attributable to the increase in the temperature and humidity; that the headache, disturbed nutrition, and febrile condition, lasting for hours and sometimes days after exposure to air thus vitiated, are either effects of the organic matter acting as a poisonous waste when taken back again into the system, or results of the suppression of cutaneous excretion dependent upon the high content of moisture in the air; and that the respiratory carbon dioxide by itself can but rarely have much influence upon comfort or health.

If the respiratory and cutaneous vitiation be sufficient

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that in some cases infection was probably due to the dust in the atmosphere which had been raised by many passing feet from the roads over which leaking sewage wagons had been hauled.

to produce acute effects, the immediate symptoms will be discomfort and a sense of oppression, followed by headache and not rarely nausea and a rather decided rise of temperature, all of which may last for some time even after the individual goes into perfectly pure air. Those who habitually live in such an atmosphere are almost uniformly languid, pallid, and anæmic, subject to headaches, nausea, and loss of appetite, and often to skin disorders, and are undoubtedly markedly predisposed to phthisis, pneumonia, bronchitis, scrofula, rhachitis, etc. Moreover, such an atmosphere apparently favors the rapid spread, increases the severity of and retards the convalescence from such diseases as diphtheria, scarlet fever, measles, typhus, smallpox, etc. This may be due either to the accumulation or to the actual multiplication by growth of the disease germs in the foul air, or to the vitiated atmosphere causing a decrease of bodily resistance and an increase in predisposition to such maladies.

When the proportion of impurities is very great, the results may be serious and even fatal, as in the well-known cases of the "Black Hole of Calcutta"; of the prison in which 300 captives of war were crowded after the battle of Austerlitz (260 dying very soon after being placed therein); and of the steamer "Londonderry," in which, of 200 steerage passengers who were temporarily crowded into a cabin (18×11×7 feet) during a storm of only a few hours' duration, 72 were dead and others dying when the cabin was opened: but in these instances the lack of oxygen may have also been a very important factor in the results.

As regards the influence of combustion-products on health, it will suffice to detail the symptoms resulting from inhalation of the various gases. It will be difficult to show that these gases, together with the coincident soot, have any general effect upon health when escaping into the out-door atmosphere, even when produced in such enormous quantities in cities as has been already indicated. It is possible that the sulphur dioxide and other sulphur gases might predispose to or aggravate attacks of bronchitis or asthma in those living in the vicinity of gas-works, chemical factories, etc., but too little comes from the chimneys of dwelling-houses to do much, if any, harm.

In-doors the case is different, for the gases from lights and fires become more and more concentrated as the ventilation is insufficient. The possible effects of varying percentages of carbon dioxide have been noted. We have no evidence of cases of chronic poisoning by this gas, although, as Parkes says: "The presence of a very large amount of $CO_2$ in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and thus in time possibly produce serious alterations in nutrition."

In cases of acute poisoning by this gas—*i. e.*, where it is in great excess in the atmosphere—there is an almost immediate loss of muscular power, and the person may consequently be unable to remove himself from the place of danger, while others who go to help him may also succumb and more than one be asphyxiated. Accordingly, volunteer rescuers should always remember to act with coolness and great rapidity, and to provide means for the prompt removal not only of the ones they would save, but of themselves as well. Fortunately, when one who has been overcome by carbon dioxide is brought into an atmosphere of pure air before life is extinct and is aided by artificial respiration, he usually recovers quickly and completely because of the rapid escape of the excess of the gas from the blood and its replacement by the necessary oxygen. Death from carbon dioxide poisoning is probably mainly due to asphyxia, partly from lack of oxygen and partly from paralysis of the respiratory muscles, of which the latter, as well as the general motor palsy, would seem to indicate that the gas itself had also a positive physiologic and toxic effect upon the nerve-centres.

Cases of poisoning by carbon monoxide are much more serious. Recovery from its effects is slow and uncertain, because this gas unites with the hæmoglobin of the red blood-corpuscles, paralyzing them as it were, and rendering them unable longer to act as oxygen-carriers to the tissues; while the union of carbon dioxide with the blood is always a much more unstable one and readily dissolved as soon as interchange with a normal atmosphere is available. Less than 0.5 per cent. of carbon monoxide in the air has caused symptoms of poisoning, and more than 2 or 3 per cent. is fatal to animals. "It appears that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot again be displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown that it may be gradually converted into carbon dioxide and be got rid of."

The symptoms of carbonous oxide (monoxide) poisoning are feebleness, oppressed breathing, trembling, and inability to swallow; then "loss of consciousness, destruction of reflex action, and finally paralysis of the heart." "Hirt says that at high temperatures (25° to 32° C. = 77° to 90° F.) it produces convulsions, but not at low temperatures (8° to 12° C. = 46° to 54° F.)." The blood and muscles are made a brilliant red by this gas; darkened by carbon dioxide. Claude Bernard says that a mixture of
gases is more destructive than either separately,
bly because the excess of the acid gas interferes

with conversion of the monoxide to the dioxide in the blood, as was shown by Pokrowsky.

Illuminating- or coal-gas—composed of hydrogen, light and heavy carburetted hydrogens, a little nitrogen, and carbon dioxide, and from 5 to 7 per cent., or even more, of carbon monoxide—rapidly causes, when inhaled, giddiness, headache, nausea and vomiting (?), confusion of intellect, loss of consciousness, general weakness and depression, partial paralysis, convulsions, and the usual symptoms of asphyxia. Mixed in large proportions with the air, death may ensue comparatively quickly, probably because of the large content of carbon monoxide. It is well to remember that the so-called water-gas, now so extensively manufactured for fuel purposes and also for diluting coal-gas, contains a much larger percentage of carbon monoxide (sometimes from 30 to 40 per cent.) than coal-gas, and that the effects resulting from inhalation of a mixture of the two will in all likelihood be more marked, more rapid, and more deadly than with undiluted coal-gas.

"The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone, which such men show, are owing to the constant inhalation of an atmosphere so impure."

Sulphurous acid gas ($SO_2$) and hydrogen sulphide ($H_2S$) are each fatal to life, the latter when in a comparatively concentrated state; but they are offensive to the senses and thus give warning of their presence, so that there is less danger of their causing serious results. Men can accustom themselves to much larger proportions of hydrogen sulphide in the atmosphere than can animals, but continued exposure to it is liable to give rise to vertigo, headache, slow and weak pulse, sweating, and loss of strength.

When sewer-gas or soil-air escapes into the outer air they are usually soon diluted beyond power for harm; but if either gains access to closed rooms or unventilated dwellings, its effects upon the inmates are depressing and decidedly harmful. In either case, concentration of the impurities may cause acute symptoms, such as vomiting, purging, severe headache and prostration; and either soil-air or sewer-gas may possibly at times carry the germs of infectious diseases. Their influence, however, is usually insidious, owing to dilution with the house-air; and the more common symptoms will probably be pallor, languor, frequent headache, loss of appetite, diarrhœa, impaired health, and often chronic anæmia. Children especially suffer in nutrition, and with them febrile attacks may be frequent; but with all, the power of resisting such diseases as typhoid fever, diphtheria, etc., is lessened and the susceptibility to them is increased, the sickness more severe, and the convalescence more prolonged. Indeed, sewer-gas and soil-air probably aggravate all diseases.

In this connection Alessi has shown that when small animals, such as rabbits, rats, and guinea-pigs, have been exposed to sewer-air for some days, by far the larger majority when inoculated with only a small quantity of a slightly virulent typhoid culture contract the disease and die, while almost none of those treated similarly in every way excepting by the exposure to sewer-air succumb. He also showed that the inoculations were more deadly when the previous exposure to the noxious gas had been less than two weeks than when it exceeded that period, indicating that animals, as well as persons accustomed to such contamination, are not apt to manifest the symptoms due to it so rapidly or so seriously as are those who experience it for the first time—a fact well known to all observers. It is only fair to say that these experiments of Alessi have apparently been controverted by other observers; but, whichever may be correct, the truth of the following quotation doubtless still holds good:

"There is undoubtedly a poisonous agency at work when sewer-gas is inhaled, which, though it may not directly act, yet so prepares the soil that the system is unable to resist the invading organism when it comes."[1]

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[1] Notter and Firth, p. 159.

## CHAPTER IV.

### VENTILATION AND HEATING.

As we are not usually able to destroy the impurities of the atmosphere within our dwellings as fast as they are produced, we have recourse to ventilation as a means for their dilution and prompt removal. We must not think, however, that we do all that is necessary if we only renew the in-door air, for unless the source and supply from which we take that which is to replace or dilute the vitiated air be pure and clean, any system of ventilation which we may adopt will be of little value.

**External ventilation** of buildings, streets, and cities is of importance, then, as well as that which relates only to the interior of dwellings, workshops, and places of assembly. Numerous investigations and statistics, both here and abroad, show that "the health of a town largely depends upon the width of the streets, the general height of the buildings, and the amount of yard-space at the rear of each which separates it from its opposite neighbor." It is also difficult to overestimate the value of wide streets, numerous diagonal ones and frequent parks or open spaces, especially in the more thickly inhabited portions of a city. In this connection we may refer with advantage to some work of Dr. H. S. Anders, of Philadelphia, in which he shows that "the number of deaths from phthisis on a very wide street is proportionately small compared with those on almost any one narrow street," and "that there is plainly and generally a high mortality-rate from consumption associated with street narrowness in not a small part of Philadelphia, and that the relation between a high mortality and narrow streets is a positive and vital one." His statistics, covering a period of fifteen years, show that in one city ward, certainly favored as to location, the ratio of deaths from phthisis per square or block on streets over to those on streets under forty feet in width was approximately as 3 is to 5.

As regards **internal ventilation,** it will be well to determine at the outset the meaning and limitations of the term. Parkes says: "It will be desirable to restrict the term ventilation to the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid or liquid excreta, and attention to the conditions surrounding dwellings." With the function of ventilation thus limited, it will not be necessary to make provision for such an abundant supply of pure air as might otherwise seem advisable. It is evident also that the purity of in-door air must almost always be relative and not absolute, especially in a climate like ours, which for a considerable portion of the year necessitates warming of the air and some consequent economy in its use.

It seems strange that attention has not been given to the possibility of purifying a vitiated atmosphere by means of fire rather than by the removal or dilution of the impurities, especially as we so often employ heat as an agent to destroy or alter the harmful qualities of other substances intimately concerned with our welfare. The objection that many would offer at first thought to such a plan is that fire would rob the air of all or most of its oxygen, but a little calculation and consideration will show that this is by no means a necessary result, and that a proper apparatus might actually consume but comparatively little of this gas and give off but little carbon dioxide as a combustion-product to the atmosphere. So far as the writer knows, but one device on the market has this function professedly embodied in it, and it apparently does what is claimed for it in this respect. The possibilities of the suggestion invite further investigation.

To discover the quantity of air desirable and consistent with the requirements of good ventilation and the maintenance of health, two factors must be determined: (*a*) the *extent* to which the air of a room is contaminated in a given time by the impurity it receives, and (*b*) the *limit of permissible impurity* beyond which there will be a possible risk or detriment to health. In accordance with the above-mentioned limitations of Parkes, the contaminating substances will usually be comparatively few in number, but the same factors are to be sought in the case of any detrimental substances in the atmosphere at any time, provided their source or cause cannot be directly removed.

Although it is extremely difficult to determine quantitatively the organic matter given off by human exhalation in any given time, the carbon dioxide, as has been stated, is usually exhaled in a reasonably constant ratio with it, and can therefore be used as an *index* of the amount of it contaminating the air. Taking Pettenkofer's figures, which have been substantially confirmed by other investigators, viz., 0.6 cubic foot of carbon dioxide per hour per head for a mixed assemblage at rest, 0.7 cubic foot for adult males, and increasing amounts according to the physical work done, we have the first factor (*a*) of our problem determined for all cases where the products of human respiration and exhalation are the only contaminants.

In establishing the limit of permissible impurity—the second factor (*b*)—it will naturally be advisable to require that the supply of air from without shall be sufficient not only to be thoroughly consistent with health, but also that there may be no perception of impurity by the senses, the air of the room remaining apparently as fresh and pure as that out-of-doors. To this end de Chaumont made a large number of observations (over 450), and found that as long as the carbon dioxide due solely to respiratory impurity did not exceed 0.02 per cent., the in-door air did not differ sensibly from that without, but that when the respiratory $CO_2$ reached 0.04 per cent. the air was rather "close" and the organic matter was becoming perceptible to the sense of smell. Subsequent investigations have shown that as long as the respiratory $CO_2$ does not exceed 0.02 per cent. it has no perceptible effect upon health; consequently, we may take this amount of carbon dioxide, over and above the amount normally present at the time in the outer atmosphere, as the limit of permissible respiratory impurity in ordinary inhabited apartments.

Having now the two factors of our problem, and provided there are no other sources of contamination, it becomes a simple matter of proportion to determine the quantity of fresh air to be supplied to each individual. The equivalent of 0.02 per cent. is 0.0002 cubic foot of carbon dioxide in each cubic foot of air. In a mixed assembly at rest each person exhales 0.6 cubic foot of carbon dioxide per hour. Consequently, to dilute properly this respiratory $CO_2$ and its coincident organic effluvia, each person will need $\frac{0.6}{0.0002}$ or 3000 cubic feet of fresh air per hour. If the individuals are all adult males, or if they are working, there must be a corresponding increase in the air supplied, running up to 6000 or even 9000 cubic feet or more per head in certain laborious occupations. This is the theoretical amount of pure air necessary for good ventilation; but in practice we find that we can get along with safety and comfort with somewhat less, because some of the bodily impurities are almost at once carried away and out of the room by the draughts through the exits, or through the cracks and crevices in the walls and ceiling which act as exits, and the incoming air does not, therefore, have to mix with and dilute that portion of the impurities that is so immediately removed. In other words, if ten per cent. of the vitiation is thus directly taken away, ten per cent. less of pure air is needed to dilute the remaining contaminants to the limit of permissible impurity; but as the quantity and the consequent velocity of the incoming or of the outgoing air diminishes, less and less of the impurities are thus directly removed, and experience teaches that almost the entire theoretical supply of fresh air is actually needed in practice to secure satisfactory results.

Provision must also be made for sufficiently diluting the impurities from other sources of vitiation whenever they are present. Although combustion-products are not usually so dangerous as impurities from the human body, and generally accumulate near the top of the room on account of their high temperature, which also facilitates their escape, we should provide at least 1800 cubic feet of air for each cubic foot of gas burned, and ten times as much for each pound of oil consumed.

In sick-rooms and hospitals an exception must also be taken to the equation in which 0.02 per cent. of carbon dioxide is taken as the permissible respiratory impurity, for it is found that the organic matter exhaled from the sick is much more offensive than that from the healthy, and is noticeable to the senses when the respiratory $CO_2$ is even below 0.02 per cent. So, at least one-fourth or more of clean air must be added to the quantity necessary for the healthy, and a good rule is to give the sick as much as possible, provided it be properly warmed and distributed.

The use of the following formula will often be of advantage in solving problems relating to ventilation, viz.: $\frac{e}{r} = d$, where $e$ represents the amount of carbonic acid exhaled in the given time, $r$ the respiratory $CO_2$ in parts per cubic foot, and $d$ the delivery or volume of fresh air in cubic feet.[1] Example: What will be the respiratory impurity in the air of a room of 3000 cubic feet capacity which has been occupied by three men for two hours supposing that there has been an ingress of 9000 cubic feet of fresh air in that time? Here $e = 0.7 \times 3 \times 2 = 4.2$, and $d = 3000 + 9000 = 12{,}000$. $\frac{4.2}{r} = 12{,}000$: $\frac{4.2}{12{,}000} = r = 0.00035 = 0.035$ per cent. carbon dioxide.

Before considering the means by which a sufficient quantity of pure air may be supplied to buildings and apartments, it will be well to note the following restrictions as to the size and height of the rooms. If a room be too small, the air therein will have to be changed often, the velocity at the inlets will be increased, uncomfortable draughts will be created, and the air will not diffuse itself so thoroughly throughout the room. Experience shows that even when the air is properly warmed, it cannot be changed much oftener than three times an hour without discomfort to the occupants of the room, unless the ventilating apparatus be very perfect in its workings and, therefore, expensive. Consequently, as we take 3000 cubic feet of fresh air to be the average amount required per person per hour, the *cubic space* per individual should be at least 1000 cubic feet, with a corresponding increase where the occupants are all adult males, are all at work, or are in hospitals.

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[1] By allowing $e$ to represent the total contamination per hour, and $r$ to represent the limit or extent of impurity in any given case, this formula can be used for almost any other ventilation problem, whatever may be the contaminants or source of impurity.

Again, it must be remembered that the difficulty of securing equable heating and ventilation increases with the height of the room above a certain limit, and that with the sick especially a certain amount of *floor-space* is necessary, both for the separation of patients and convenience of attendance. Ten or twelve feet will usually be found to be the safe limit of height for all apartments intended for continuous rather than temporary occupation, and consequently there should be a minimum allowance of from 85 to 100 or more square feet of floor-space per head, and even an increase above this in workshops, hospitals, etc. However, there is no objection to high ceilings if one is not limited as to floor-space, pure air-upply, and heat; and they are even advisable in rooms where many lights are to be burned. Again, these restrictions regarding cubic and floor-space do not necessarily apply to such buildings as churches, theatres, etc., which are occupied for only a comparatively limited time, which can be thoroughly flushed out after use, and in which it is evidently impracticable to allot to each person the above floor-area. Yet pains must be taken in such assemblies to keep the atmosphere pure by whatever means are necessary; while for school-rooms and the like there must be extreme care that the pupils are not over-crowded, and that they have a full supply of properly warmed air.

Any correct system of ventilation, in addition to the above considerations, must take into account the source of the air supplied, the distribution, and the heating or cooling of the air when necessary.

The air supplied to any house should be taken from well above the level of the ground, where it is free from contamination and is constantly changing, and not from cellars or closed areas, where the atmosphere is stagnant and full of impurities. The conduits leading to the heating or ventilating apparatus should also be so arranged that they may be frequently and readily cleaned. It is well to have them covered with gratings to prevent objects being thrust into them, and in some cases it may even be advisable to filter the air through coarse cloth or fine wire gauze to free it from dust and other impurities. In the mechanical system of ventilation adopted in the chemical laboratory of University College, Dundee, the air is filtered by being passed through jute cloth (light Hessian) stretched on frames seventeen feet long by four feet wide. In this case the presence of the screen actually increased the delivery of the air by nearly 10 per cent., probably by preventing eddies. The screens collected two and one-half pounds of dirt in seven weeks. They last about a year, and the cost is about 2*d* (four cents) a yard.[1] In the clinical amphitheatre of the Medico-Chirurgical

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[1] Stevenson and Murphy, vol. i., p. 51.

College and Hospital of Philadelphia a double thickness of fine wire gauze is used to filter the air after a preliminary spraying with water, the result being entirely satisfactory.

The air may be kept in motion and efficient ventilation secured (1) by those forces more or less continually acting in nature, producing *natural ventilation*, and (2) by these in combination with other forces set in action by man, giving *artificial ventilation*.

**Natural Ventilation.**—The three main forces of natural ventilation are diffusion, the winds, and the motion caused by the difference in weight of volumes of air of different temperatures. Diffusion is constantly taking place between all the gaseous constituents and impurities of the air, and even effects a change through brick and stone walls, but alone is insufficient to keep the air pure, though it does much to further this. Moreover, as suspended matters are solid, not gaseous, they are not changed or removed by it. As the rate of diffusion increases the greater the difference in specific gravity between two gases or atmospheres, it goes on rapidly when there is much difference of temperature between the in-door and outer air, and also at the top of rooms, where the warm impurities tend to accumulate.

However, the action of this force should not be ignored in our calculations as being insignificant, for it is not only continuous, but it also affects the whole volume of the atmosphere in maintaining its uniformity of composition. "Roscoe found that when he evolved carbon dioxide in a room the amount had decreased one-half from that cause (diffusion) in ninety minutes."[1] The rate of diffusion is inversely as the square roots of the densities of the gases concerned.

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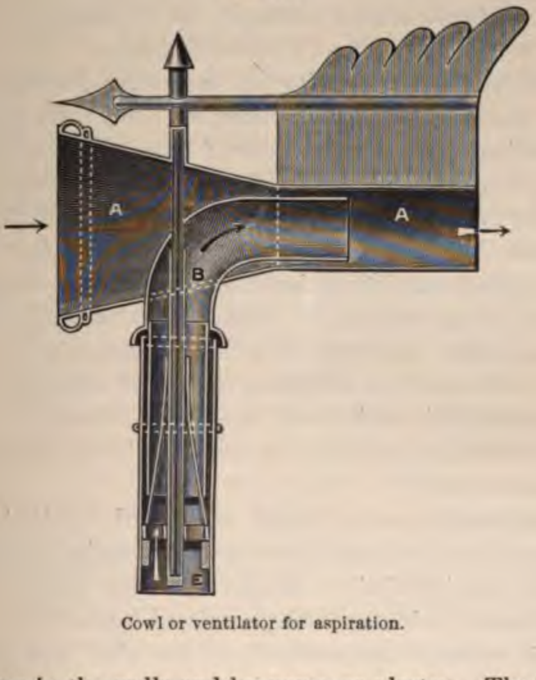
[1] Notter and Firth, p. 194.

Winds are powerful agents for ventilation, and a slight breeze passing through a room changes the air therein many times in the course of an hour, and carries out by its force many of the solid impurities not affected by diffusion. Wind will pass through walls of wood, brick, or stone, although its progress is markedly arrested by much moisture in the walls and by paper or plaster. The average rate of movement of the wind is considerable, but the disadvantages in utilizing it in ventilation are the uncertainty of its direction and velocity, the difficulty of regulating it, and the fact that it may fail us at a time

FIG. 13.



Cowl or ventilator for aspiration.

when we need its action most. In winter it usually has to be excluded directly from our houses, because a velocity of five or six feet per second is not to be borne unless the air be previously warmed. We may, however, take advantage of the fact that a small current with a high velocity will set in motion a large volume of air, and that wind blowing across the top of a tube will cause an upward movement of air in the tube. This is one reason why there is almost always a draught up an unused chimney and why it acts as a good ventilating outlet.

To utilize these perflating and aspirating powers of the wind, and to prevent back-draughts down chimneys and ventilating pipes, we make use of so-called *ventilators* or *cowls*, either movable or fixed. We can so arrange these that the force of the wind either drives air into the house (perflation) or draws air out of it (aspiration). Very good systems employing these have been put in operation, the air being warmed, if necessary, by passing it over stoves, steam coils, etc., and they are especially useful where the inner air is colder than that externally, and where artificial methods of ventilation dependent upon heat cannot be employed, as in the holds of ships, deep basements, etc.

The most important agent in natural ventilation is, however, the movement produced by variations in the specific gravity of air. Though the wind might be included under this head, being produced by the same force, the air is moved independently of the wind, especially in closed buildings. As the air expands when heated, it becomes lighter, volume for volume, and rises because the colder, heavier air pushes in beneath to occupy the space. But in all inhabited apartments a warming of the atmosphere is continually taking place, not only by the lights and heating apparatus, but also by the bodies of the occupants. The movement is, therefore, a continual though not necessarily an equable one, varying as it does with the temperature of the out-door air and the number and intensity of the heating agents within. There being such a warming and movement of the air, it follows that, unless a room be perfectly air-tight, some of the apertures will act as inlets and others as outlets, and the quantity flowing out of the room will be practically equivalent to that flowing into it. Therefore, though this force may not be so powerful or efficient as strong winds at certain times, yet being more constant, more readily determined or calculated, and more controllable, it is the one most to be considered in arranging a system of ventilation.

To determine the velocity of the influx or outgo of air, we make use of the law that a fluid passes through an opening in a partition between two volumes of the fluid with the velocity which a body would acquire in falling from a height equal to the difference in level of the fluid on the two sides of the partition. In the case of a current of air we substitute for the difference of level the difference in pressure on the two sides of the partition or opening, and this is expressed by the difference in temperature multiplied by the difference in height of the openings of entrance and exit, and divided by 491, $\frac{1}{491}$ representing the expansion of the atmosphere in volume and the lessening of density for each degree (Fahrenheit) of rise in temperature. The velocity will, therefore, equal

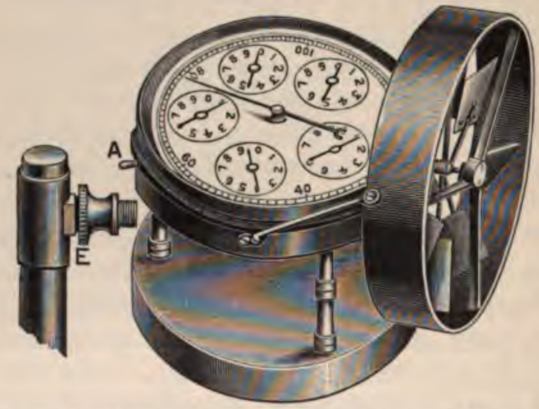
$$8\sqrt{\frac{(\text{diff. in temp.}) \times (\text{diff. in height}).}{491}}$$

Example: What is the velocity of the current in a chimney 40 feet high, the out-door temperature being 20° F.

and in-doors 70° F.? Answer: $V = 8\sqrt{\frac{50 \times 40}{491}} = 8 \times 2+$, or about 16 feet per second.

In actual practice use is made of a table derived from this formula, or else the velocity is determined directly by means of the *anemometer*. Allowance must be made for the friction of the air against the sides of the ducts and against itself, amounting to from one-fourth to one-half of the theoretical delivery, according to the length, size, straightness, etc., of the inlets and outlets. The friction will be inversely as the diameter of the openings and directly as the length of the tubes; the shape of the openings also affects it, and right angles diminish the current one-half. Accumulations of dust and dirt greatly lessen the velocity.

FIG. 14.



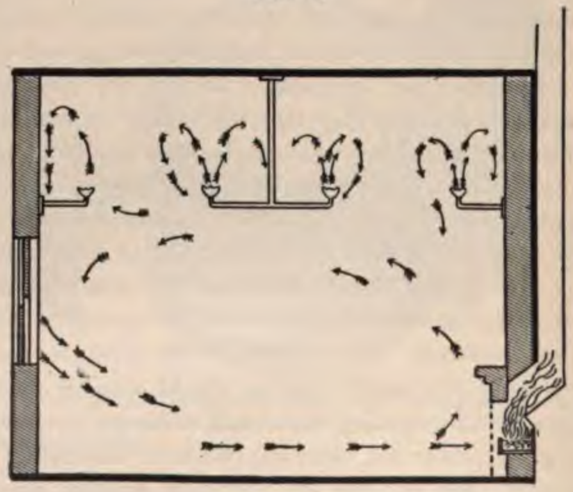
Anemometer, used for measuring the velocity of air-currents directly; A, slide for releasing or stopping the dial hands; E, support for attaching the instrument to a staff or cane.

The velocity multiplied by the total area of the inlets or outlets, with a proper allowance for friction, will give the quantity of air passing through the rooms or series of rooms in any given time.

One of the most difficult problems in natural ventilation is to secure a uniform distribution of pure air through the rooms, and to remove the impure air as fast as the pure air is supplied, thus preventing its mixing with the latter. Certain circumstances always make the question complicated: the size and number of inlets and outlets, the rate and direction of motion, and the forces acting to produce it must always be subject to constant change, and must thus constantly alter the result. In fact, it is practically impossible to devise a plan that will satisfy all conditions at all times, and the best that can be done will be to select that one which will give the greatest efficiency and most satisfactory results under all ordinary circumstances.

The force of diffusion will always act as long as there is any difference of temperature and any communication between the exterior and interior, and no special attention need be given to it. For reasons already given, we cannot use the wind continually, but we should employ it whenever possible by opening doors and windows, on account of its great power for sweeping out solid impurities and thoroughly changing the air. In cold weather, currents from windows, etc., should be directed toward the ceiling, so that they may be diffused and partially warmed before reaching the inmates of the room. Numerous devices have been suggested for introducing unwarmed out-door air without discomfort, or for diffusing it through the room: among these may be mentioned perforated bricks, or double-paned windows, valves, screws, etc. A cheap and satisfactory temporary arrangement is to place a board about four inches wide and as long as the width of the lower window-sash beneath the latter. Or, better, have a light frame covered with fine netting or wire-gauze, four or five inches wide, made to fit above the upper sash: the fresh air from without can now enter freely between the upper and lower sash, being reflected upward by the inner surface of the glass in the upper sash, and thus mixing with warm air before reaching the occupants of the room; while the frame at the top of the window becomes an outlet for the foul air, the interference of the netting or gauze preventing too rapid an outgo and consequent loss of heat. But in a climate such as our own, and in all cold countries, special measures must be taken during a large part of the year for warming the out-door air before introducing it into occupied rooms.

Fig. 15.

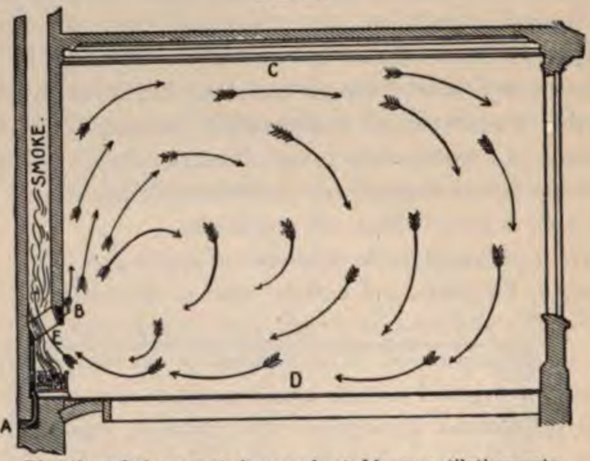


Direction of air-currents in room lighted by gas and heated by open grate.

Where we intend to depend most upon the third force of natural ventilation, viz., the movement of unequal weights of air, we must provide other openings for the entrance and exit of the air than the windows and doors, so that there will be a practically constant movement through the rooms in a given direction, that we may be sure the air is from a pure source, and that we may get the utmost service from our appliances.

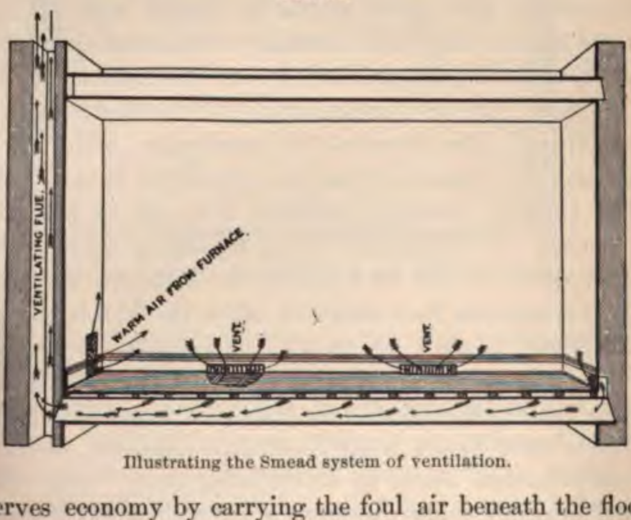
There is considerable difference of opinion as to the best locations for inlets and outlets, and as the conditions are necessarily different in every case and so many factors are to be considered, it is difficult to lay down general rules. It should be an aim, however, to have the air well distributed throughout the room or rooms and to have no direct draughts from the inlets either upon the occupants or to the outlets. It is the writer's opinion that usually the outlets should be located near the top of the room, owing to the tendency of the used air to rise, and because in unventilated rooms the foulest air for some time after its contamination will be found nearest the ceiling. The products of combustion from lights, etc., will also practically all be in the upper strata of air. (Fig. 15.) If, however, provision is or can be made for a constant and sufficiently strong aspirating force in the outlet ducts, it may be advisable to withdraw the used air from near the floor level and below the inlet openings, though not in too close proximity to them, since in this way a more thorough distribution of the incoming air and a greater dispersion of its contained heat are secured. This is aptly shown in the illustration depicting the currents in a room heated by a ventilating grate. (Fig. 16.) This principle is also involved in the well-known Smead system of ventilation and heating, which still further

FIG. 16.



Direction of air-currents in room heated by a ventilating grate.

FIG. 17.



Illustrating the Smead system of ventilation.

serves economy by carrying the foul air beneath the floor of the room from which it is taken, thus warming the floor with what heat the waste air yet contains and securing the utmost benefit and service from the fuel. (Fig. 17.)

The location of the inlets should depend on the temperature of the incoming air; if it is cold, it should be admitted near the ceiling, so that it may diffuse and be partially warmed before reaching the inmates of the room; if it is warmed, it may come in near the floor or below the middle level of the room.

Where much fresh air is required, it is better to have a number of inlets and outlets than one large one of each, as the distribution is then more certain. The total area of the outlets may be the same as that of the inlets, as the expansion of the air is scarcely sufficiently great to require a difference. The outlets should all be on the same level; otherwise the highest one will be the one of greatest discharge, and often the only one, the others possibly acting as inlets and drawing air from an impure source. As the temperature varies from time to time, and with it the current, some arrangement is needed for regulating the size of the openings of the inlets or outlets to suit the varying conditions. To supply 3000 cubic feet of air per head per hour a velocity of 5 feet per second will require an inlet opening of 24 square inches for each person; but practically it is better to have a larger opening, as the above velocity is uncomfortable unless the air be well warmed. Outlet tubes should always be protected from cold and kept as warm as possible.

As long as there is a fire in a grate or stove connected with a chimney there will be a constant upward current in the latter; and the area of the chimney's cross-section being known, and the velocity determined by the anemometer or by calculation, as already indicated, the amount of air passing out of the room in this way may readily be determined. In this connection it may be stated that a chimney may thus act as the only outlet and all other openings into the room may serve as inlets, especially when the fire is brisk, the outgoing current, of course, being practically equivalent to the amount of incoming air. Moreover, the outgoing current may be so strong as to overtax the capacity of the inlets, in which case more or less of a vacuum will be created within, so that the outside pressure may cause down draughts in the chimney from time to time and a driving back of the smoke and gases from the fire into the room. The obvious remedy is to enlarge the inlet area by opening a door or window, or to lessen the exit draught by means of a damper in the chimney. On the other hand, the inlets may be so large and the current so strong that the air coming into the room cannot be properly warmed, in which case, again, the size of the outlet should be lessened by a damper, or there should be an increase in the efficiency of the heating apparatus.

When we wish to draw air from distant and non-communicating rooms, the ducts may be led into a chimney below or just above a fire, or, better, into a flue or shaft alongside or encircling the heated chimney. When the exit ducts open into a chimney or smoke-stack the draught is greater just above a fire than below it, but the conduits should not enter near the top of the chimney, for there the extracting power is not so great and there is danger of high winds blowing smoke and foul air back into the rooms. Outlet flues may be constructed alongside chimneys that are being constantly used; they should be as smooth as possible interiorly, and should be as high as the adjoining chimney, to avoid down draughts. The openings from the rooms into these ducts should be as near the ceiling as possible, to get the benefit of the higher temperature of the upper strata of air, unless, as previously indicated, there is certainty of the extracting force being constant and sufficiently strong, when the air may be taken from a lower level.

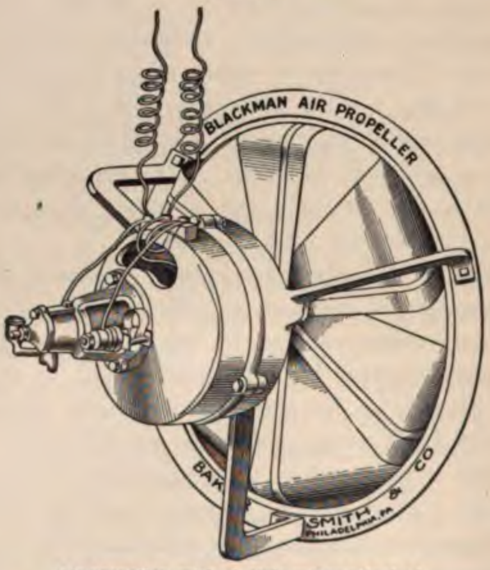
**Artificial ventilation** is that which is brought about by the intentional application of the above mentioned and other forces, and by means of special mechanical apparatus and devices, in contradistinction to natural ventilation, which may act independently of human cognizance and intention. It consists in either extracting air from or forcing air into a room or building, or in both together. The object may be attained by heating the air by special heating apparatus in the outlet, or by warming the outlet itself, or by the use of a fan, a screw, or a steam- or water-jet in either the inlet or outlet.

In hospitals and other places where a constant and independent supply of heat can be afforded, extraction shafts apart from chimneys may be used. These extraction shafts may be heated by fires, steam pipes, or steam-jets at the bottom, or by steam or hot-water pipes coiled around the sides. Some system like the following is sometimes used in mines where large quantities of air must be extracted. There are an entrance and an extraction shaft; large fires are constantly maintained at the bottom of the latter, the air is drawn down the former, diverted through all parts of the mine by partitions, and finally heated and carried up the extraction shaft.

We may also use a jet of steam or water in place of heat to extract air through a shaft, the openings of the foul-air ducts being just behind the jet. It is said that a steam-jet may thus set in motion over two hundred times its own bulk of air. Lastly, fans driven by steam- or water-power are employed to extract the air, though these are usually more efficient in forcing in air. One of 36 inches diameter at 600 revolutions per minute will propel or extract over 18,000 cubic feet of air per minute.

In ventilation by propulsion or driving in air, these large revolving fans are generally used. The advantages of this, the *plenum*, system of ventilating are the certainty as to the direction of current and amount of air supplied and the ease with which the quantity can be altered or measured, as well as warmed; also, by maintaining a slight excess of supply, leakage into the rooms of cold or foul air from without is prevented. The disadvantages are the high cost of power in most cases, the inconvenience or danger from prolonged stoppage from accidents to

FIG. 18.



Air propeller, with electric motor attached.

the apparatus, and some difficulty in distributing the air. For instance, if it be forced in through small openings or at too great a velocity, it will not mix properly with the air of the room. This last objection can usually be obviated by giving special attention to the size, direction, and arrangement of the inlet flues, and the relative location, size, etc., of both the inlet and outlet openings. The increased use of electric motors and lowered cost of running them will doubtless serve to make this system of ventilation more common in the near future.

In very large buildings it may be advisable or necessary to combine the plenum or propulsion with the exhaust or vacuum system, using power fans both to drive in and to force out large volumes of air. In this way an almost ideal ventilation may be secured, provided the incoming air be clean and be sufficiently warmed by means of steam or hot-water coils or radiators (see pages 140 and 142).

Parkes and Kenwood summarize the essential and practical points of ventilation as follows:

"1. When air is heated, it expands and tends to rise; when air is cooled, it contracts and tends to fall.

"2. Cold air tends to enter a room and to move about very much as water would; and this holds true so long as the temperature of the fresh air remains lower than that in the room.

"3. The extent of inlet provision is not quite of the same importance as that for the exit of foul air; for if foul air is extracted in sufficient quantities, fresh air will enter somehow to replace it, as by skirtings, crevices in doors or windows, or even through brick-work in walls.

"4. While the inlet provision for fresh air should average 24 square inches for each individual, several small inlets not too near each other are preferable to one large one; and the provision of inlet areas somewhat larger than those of exit tends to minimize draughts.

"5. Inlets should be as low in the room as possible—*i. e.*, just above the floor (so as not to raise the dust)—if the outside air is warm or has been warmed prior to entry; but at a height of five feet or more if the outside air is cold: otherwise unpleasant draughts are experienced. As a further protection against unpleasant draughts when cold air is admitted, the incoming air should be directed upward; while hot air, since it tends to rise, should be directed downward.

"6. Outlets should be as high as possible, and preferably close to or in the ceiling; and they should have their extractive powers maintained by means of heat or of an exhaust fan, or they are liable to act as inlets.

"7. If possible, outlets should be so placed that vitiated air is drawn toward them before mixing with the general air of the room.

"8. The tendency for fresh air to take a direct course to the outlets must be overcome by judicious selection of the positions of inlets and outlets.

"9. Methods of ventilation devised to ventilate *crowded* premises are generally inefficient unless the incoming air can be warmed in winter to about 60° F.; for efficient ventilation by cold air cannot be tolerated, and there is a great tendency among workers to close all ventilating inlets.

"10. With less than 250 cubic feet of space for each person, ventilation can never be satisfactory without the aid of mechanical force.

"11. The source of the incoming air should be considered. It should not be borrowed from adjoining rooms, but taken directly from the outside. One great advantage of the more expensive mechanical system of ventilation is the fact that sufficient air can alway be obtained from a source that is known and selected.

"12. Ventilation dependent on the extraction of foul air is more convenient and satisfactory than that in which propulsion is mainly relied upon; but the purity of the air is not provided for so easily.

"13. Warmed air forced into a room should be raised only to a temperature sufficient to prevent a feeling of cold (about 60° F.). More highly heated air is often felt to be over-dry and unpleasant."

**House-warming.**—In cold countries there must be some resort to artificial heat in the winter season,. and as this subject is more or less inseparably and closely connected with ventilation, it may be appropriately considered at this time. Cold is depressing, uncomfortable, and sometimes dangerous to the young and aged and to women whose habits of life keep them much in-doors; though well-fed, healthy adult men may not be much affected if accustomed to it. In this country we need a higher temperature in our houses than in Great Britain, on account of our drier climate; evaporation and consequent cooling of the body take place more rapidly here, and so, while they are accustomed to a temperature of from 60° to 65° F., we find from 65° to 75° F. to be no more than comfortable.

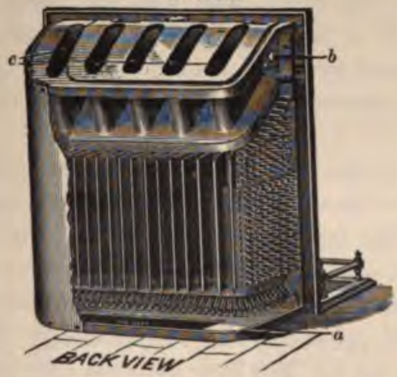
It needs but slight investigation to determine that we practically make use of but two kinds of heat—radiant and convected—in the warming of houses, and that of these the latter is by far the most generally employed and the most economical. *Radiant* heat, although it is considered to be the most healthful and warms an object directly without raising the temperature of the intervening air, has the disadvantages of utilizing but a small proportion of the fuel-value, of decreasing directly as the square of the distance of the object from the source of heat, and of thus being available only in comparatively small apartments. Our best example of radiant heat is that which comes from open fires, though any highly heated object, as a stove, gives off more or less of it.

Heat that is carried from one place to another by warmed masses of air, water, or steam is said to be *convected*, and because of the economy in its use and the ease of distribution, especially in large spaces, it is the kind most generally used. Conducted heat, which passes from molecule to molecule of the conducting substance, acts too slowly to be available to any extent in house-heating and may, therefore, be omitted from this discussion.

Just here it may be remarked that under present conditions there are three things, any two of which we may have in cold climates or weather, but not all three together, except in rare instances: they are, good ventilation, efficient heating, and cheapness. The reason for this is that any good system of ventilation necessarily and continually carries off a large quantity of air and the heat it contains, which latter is lost for warming purposes and ust be replaced at the expense of more fuel. A heat- it cannot be used at the same time to produce ventila- n and to warm objects other than the air it keeps in tion. The principal aim, then, in establishing any sys- n of combined ventilation and heating must be to warm, troduce, and carry off no more air than is necessary for e requirements of good ventilation and health, and to oduce the heat for warming this air and the house itself economically as possible, though care must also be had to secure evenness of distribution, absence of uncomfortable draughts, etc.

The usual appliances for house-heating are open grates or fireplaces, stoves, and hot-air, steam, and hot-water furnaces. To these may now be added electrical heaters, but the cost of maintaining the latter prevents their use at present by any but the wealthy.

FIG. 19.



Jackson's ventilating grate. The outer casing is cut away to show space and surface for warming the incoming air. The air enters through the oblong inlet (*a*) and passes to the register opening (*b*) (in front) between and around the five smoke-pipes (*c*) above.

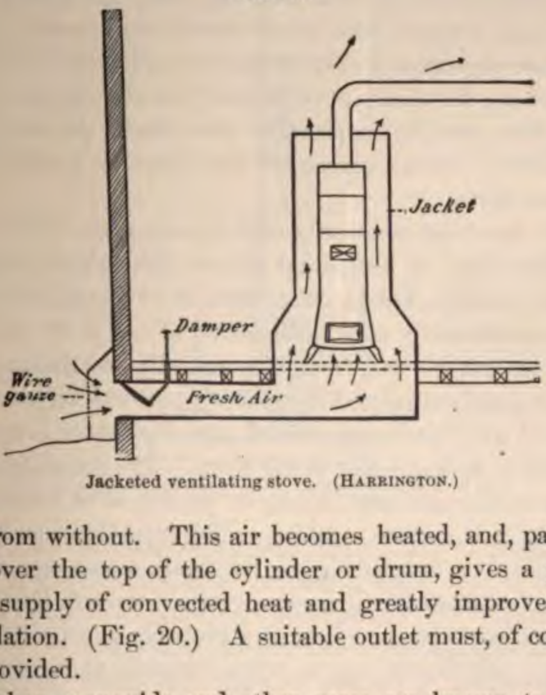
Ordinary grates and open fireplaces give practically only radiant heat, and render available only from 7 to 12 per cent. of the fuel efficiency. They also heat directly only the surfaces facing them of objects in the room, leaving the remainder cold, and by reason of the strong current up the chimney are also apt to bring in large quantities of air from without that has not been properly warmed, and thus to cause chilling and injurious draughts. Where there is some additional means of heating the air before it enters the apartment and where the chimney current is controlled by a damper, they are valuable, not only for the good ventilation they produce, but for the pleasing effect of the exposed fire as well.

To make open grates more effective for heating, the sides and top should be inclined to the back at an angle of 135 degrees, so as to throw as many heat-rays as possible into the room; the fuel surface should be concentrated, and there should be a damper to prevent too rapid combustion and too much heat and air escaping up the chimney. It is to be understood, of course, that the objects warmed by the radiant heat of the open fire do in turn give convected heat by warming the air surrounding them.

If, however, the back and sides of these grates be surrounded by a space through which air can pass and be warmed by the heat that would otherwise be wasted, we shall have a much more satisfactory apparatus, since we thus get both radiant and convected heat and may obtain from 25 to 35 per cent. of the fuel efficiency. And if clean out-door air be led into this air-space and thus warmed before entering the room, the ventilation will be greatly improved, other inlets will be unnecessary, uncomfortable draughts will be avoided, and there will be sufficient heat provided for one or more apartments of moderate size. The air-chamber at the back should not be too small, and there should be as much heated surface to warm the incoming air as possible. (Fig. 19.)

Stoves utilize a considerable percentage of the fuel—75 to 80 per cent. or more—but do not remove much air; so ventilation has to be provided for in some other way and is apt to be neglected. Stoves may also give off dangerous gases and products of combustion if not properly cared for or if the damper in the stove-pipe be entirely closed. There should be as much surface exposed as is possible without diminishing the combustion, so that there may be increased radiation and that much air may be warmed moderately rather than a little excessively. It is often advisable, especially in assembly- or school-rooms and the like, to surround the stove with a sheet-iron cylinder extending from the floor toward the ceiling, and to bring in between this and the stove a supply of fresh air from without. This air becomes heated, and, passing out over the top of the cylinder or drum, gives a plentiful supply of convected heat and greatly improves the ventilation. (Fig. 20.) A suitable outlet must, of course, be provided.

FIG. 20.



Jacketed ventilating stove. (HARRINGTON.)

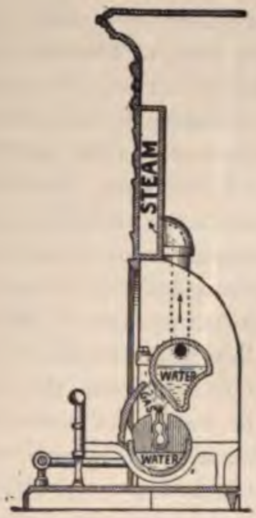
Carbon monoxide and other gases are known to leak through cast iron when it is highly heated, so that stoves should not be allowed to become too hot. The production of carbon monoxide is most abundant soon after fresh fuel is added to the fire, and is evidenced by the characteristic blue flame above the coals. If at this time the escape of this gas into the outer air is prevented by the careless or accidental closing of a damper in the stove-pipe or chimney, it is prone to pass through the top and sides of the stove in the manner indicated, and to cause the serious and fatal results so often reported. Therefore, it should not be possible to cut off completely the draught from any coal-burning stove, nor should it be materially lessened until combustion is well under way.

Other objections to stoves that are allowed to become too hot are the excessive dryness of the atmosphere which they cause and the unpleasant odor due to the scorching of floating organic substances that come in contact with the hot iron.

The fuel most commonly used in both grates and stoves is either wood or some kind of coal (bituminous, anthracite, or cannel); but gas may often be advantageously and more satisfactorily employed instead of any of these, since the heat can be had from it practically instantaneously, can be closely regulated in quantity, and can be promptly checked when no longer desired, and since there is no production of dust or ashes in the room. The main objection to gas is that for large rooms or prolonged or continuous heating, it is usually more expensive than the other fuels; but this does not hold good for small rooms, nor sometimes for isolated apartments or where warmth is needed only temporarily; and it is very probable that before long fuel gas will be—it can be now—supplied at rates which will justify a much more extended use of such fuel.

The ordinary kinds of gas-grates and gas-stoves, especially those which consume the gas incompletely, should all be constructed with flues to carry off directly the products of combustion, and this particularly when any large quantity of gas is used. Theoretically, when the gas is burned in a properly adjusted Bunsen or "atmospheric" burner, the only combustion-products will be carbon dioxide and water, the former of which is rapidly diffused into the outer air, as has been shown, and is not likely to be harmful in any quantities thus produced, while the aqueous vapor is beneficial to the atmosphere rather than otherwise. However, it seems that in practice even these Bunsen burners may sometimes give to the air a disagreeable odor (said to be due to the formation of acetylene), and so occasionally need flue connections.

FIG. 21.



Section of Backus' portable steam radiator for use with gas.

In this connection it may be interesting to describe one form of gas-heater which, so far as the writer knows, is unique. It is intended not only to consume perfectly the gas it uses, giving nothing to the air but carbon dioxide and water, but also to destroy by fire the impurities of the atmosphere of the room, thus doing away with chimneys or flues and the necessity of much ventilation. By a peculiar arrangement a continuous and large current of air is made to pass through the flame, thus burning the impurities whether gaseous or solid. The heat of the burning gas is also used to convert a quantity of water into steam, which, by heating the containing chamber or coils of pipe and these in turn the atmosphere surrounding them, warms many times the volume of air possible to heat by the flame alone. In addition, the humidity of the atmosphere is maintained by the evaporation of water from an open basin beneath the fire.

The ordinary openings of any room are amply sufficient to allow diffusion of the excess of carbon dioxide—one-half escaping in this way, according to Roscoe, within ninety minutes—and to permit the ingress of enough air to supply all the needs of the inmates and of the fire itself. Experience and careful experiments seem to show that the claims of the inventor are well founded, and that the apparatus is healthful in its operation and produces no harmful effects even after continued use for several months. At any rate, there seems to be no reason why we may not purify the air by fire instead of by dilution and removal, the methods employed in the hitherto described systems of ventilation.

Oil-stoves are now used quite extensively, and, beside being portable, have the same advantages as gas-stoves, viz., that a considerable quantity of heat may be had quickly and just as long as it is desired, and at a fairly moderate cost. The combustion-products necessarily mix directly with the atmosphere of the room, and where reasonably perfect burning is had doubtless consist of little else than carbon dioxide and water. One pound of oil, the hourly consumption of a rather large stove, will require about 150 cubic feet of air for its complete combustion, and will produce about 25 cubic feet of carbon dioxide.

"We do not think that the experience has yet been accumulated which would enable us to speak positively of the innocuousness of a considerable admixture of carbonic acid with the air we breathe; but the knowledge that in hundreds of cases oil-stoves are used for heating living-rooms and even bed-rooms, without apparent injury to the occupants, makes one feel fairly confident that the products of the complete combustion of hydrocarbons are not injurious when mixed with such an amount of air as is sufficient to dilute to a proper degree the respiratory products. . . . Experiments show that, provided the combustion of the oil is complete and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil-stoves for heating purposes may be advantageously employed in both day-rooms and sleeping-rooms. The efficacy of oil-stoves is increased by placing over them a diffuser or radiator, so as to prevent the heated products ascending direct to the ceiling; care needs also to be taken that only the better kinds of mineral oil are used; if inferior qualities of oil are burnt, perfect combustion is more difficult to obtain."[1]

The above remarks, as far as they apply to the healthful use of the air, may probably be used with equal justice in regard to gas-stoves, provided that with such dilution their products give no obviously harmful or disagreeable results.

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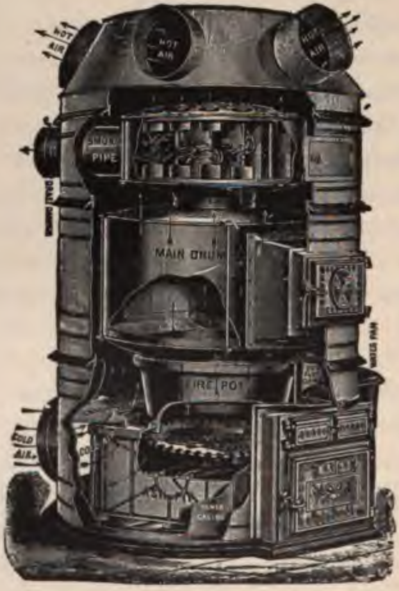
[1] Notter and Firth, p. 228.

The heating apparatus thus far described is such as we are accustomed to employ for warming the air of single or possibly of adjoining rooms. Where a whole dwelling or other large building is to be heated, it will usually be of advantage to do this from one point, and that not in any of the living apartments. In this way we shall have a centralization of fuel, both unburned and burning, and the ability to derive more heat from it; a lessening of the labor and attention bestowed on the fires; the obviation of much dust, dirt, and combustion-products in

Fig. 22.



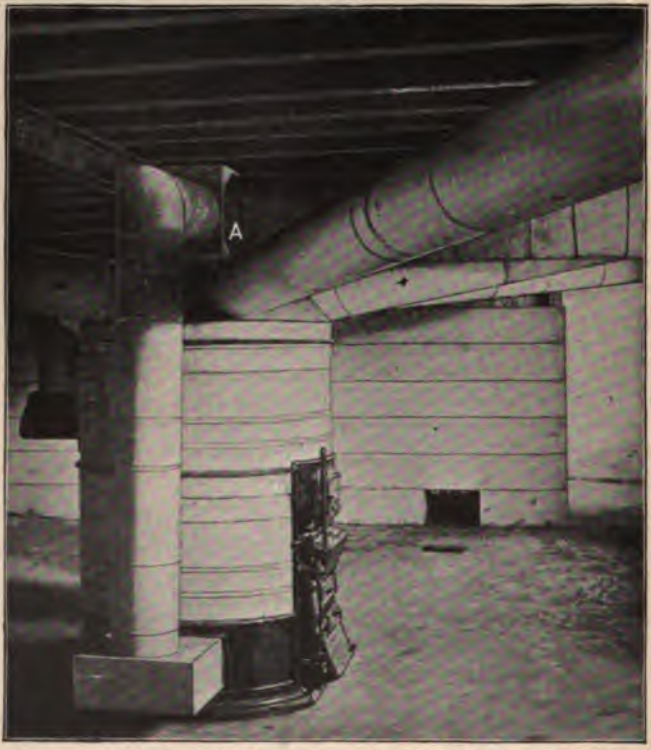
Spear's hot-air furnace.

living-rooms, and, presumably, a more equable and satisfactory warming of the whole building. From such a central point the heat is distributed by hot air, hot water, or steam, or by hot air in combination with either of the two.

Hot-air furnaces supply a large amount of convected but no radiant heat. There is a very prevalent opinion that they are not healthful, and that wherever possible they should be replaced by some other means of heating. But when properly constructed and cared for, a hot-air furnace of the proper size is not only a good heater, but also a powerful ventilating agent, for the large supply of air passing through it into the rooms above must in turn find an exit either through specially devised outlets or through the innumerable cracks and crevices around all doors and windows, and the ventilation will be accordingly.

One frequent source of trouble is too small a fire-pot, giving insufficient heating surface and necessitating too rapid and too intense combustion of fuel. There should be a considerable expanse of surface, never too highly heated, so that large volumes of air will be moderately warmed rather than small quantities overheated and "burned." Air too highly heated is very dry and offensive to the senses; also, by taking excessive moisture from the body through the skin and mucous membranes and by exciting glandular activity, it increases the liability to frequent "colds" and congestions. Moreover, a large quantity of air moderately warmed will perforce be carried to *all* the rooms of the house, warming them equably and driving before it the air already there: whereas a much smaller volume, excessively heated by the same or even a greater amount of fuel, will make its way along the channels of least resistance to a few favorably located rooms, overheating them while the rest of the house is unwarmed, and any satisfactory natural ventilation is prevented.

FIG. 23.



Hot-air furnace, showing cold-air inlet and hot-air flues. Only one of the lateral branches of the main inlet (*A*) above is shown.

All joints in the furnace must be as nearly gas-tight as possible to prevent the combustion-products passing from the fire-box or smoke-flues into the air-chambers and thence into the rooms above.

The furnace should be located near the cold side of the house—that is, the side on which the prevailing cold winds impinge—for it is said to be as difficult to drive the air ten feet against the wind as forty or fifty feet with it. It may also be well, if the basement ceiling is low, to place the ash-pit below the level of the basement floor, in order to give sufficient slope to the air-ducts; but in every case the space beneath the furnace should be floored and lined with cement or asphalt to prevent the drawing in of soil-air.

The air-supply should not be taken from the cellar, even though the latter be apparently clean and free from contamination with soil-air, but should come from a clean source out-of-doors, well above the ground-level and from the direction of the prevailing winds. The cold-air duct or ducts should be screened at the entrance to prevent the admission of refuse or vermin, should be arranged to permit of regular cleaning, should have a damper to regulate the supply of air, and should have a cross-section of at least two-thirds of the combined sectional area of the hot-air flues leading from the furnace. The importance of a large air-inlet cannot be too strongly emphasized, for upon this feature may most depend the satisfactory action of the furnace. It may be desirable to provide for filtration of the air through coarse cloth or fine wire-gauze, especially if there be much dust in the incoming air.[1]

If possible, the hot-air flues or ducts should not be too narrow in cross-section, but round or square to lessen friction; and for the same reason they should be as direct in their course and as nearly vertical as possible. They should be covered from the furnace to the register-openings with asbestos or other non-conducting material to prevent the loss of heat that otherwise escapes from them into the cellar and between the partitions. Lastly, their register-openings into the rooms should not face the windows or prevailing winds, unless it be unavoidable, for if they do the passage of warm air into the rooms will often be almost if not completely checked.

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[1] See page 107.

The following table, from Coplin and Bevan, gives the proper size for hot-air flues and registers:

FIRST FLOOR.

| Size of room in cubic feet. | Size of pipe. | | Size of register. | |
|---|---|---|---|---|
| | If round. | If square. | If round. | If square. |
| Less than 1500 . . . . . | 7 inches | 4 × 9 inches | 9 inches | 7 × 10 inches |
| 1500 to 2000 . . . . . . | 8 " | 4 × 12 " | 10 " | 8 × 10 " |
| 2000 to 3000 . . . . . . | 9 " | 4 × 16 " | 12 " | 8 × 12 " |
| 3000 to 4000 . . . . . . | 10 " | 4 × 18 " | 12 " | 9 × 14 " |

Economy will be subserved in most cases by taking care to burn the fuel in hot-air furnaces quite slowly, since in this way larger quantities of air are warmed and more satisfactorily, and there is also less waste of heat through the smoke-flues and up the chimney. Moreover, it is the experience of the writer that by working the furnace in this way at low pressure, so to speak, the air from it will be less likely to become too dry, nor will it need the addition of so much moisture, something essentially necessary and yet most often neglected where comparatively little air is excessively heated.

The amount of water to be added also depends upon the humidity and temperature of the out-door atmosphere.

When the latter is but little, if at all, below the freezing-point and is almost saturated, and when the in-door air is but moderately warmed, as suggested, the lack of added moisture may scarcely be noticed; while if the air without be at the same time dry and very cold, its actual content of water will be very little, and much added moisture will be needed to make it either comfortable or healthful, even though warmed to only a moderate degree.[1]

"Concerning the need of insuring a normal amount of moisture in the air of heated buildings, there is more or less difference of opinion, but the weight of evidence from a medical standpoint, and from our own sensations, points to the advisability of introducing an amount of moisture sufficient to bring the relative humidity of the air to 50 or 55 per cent. . . . Air at 25° F., saturated with moisture and then heated to 70°, would need over a half-pint of water in every thousand cubic feet to give it a humidity of 65 per cent., and this is far in excess of the capacity of the ordinary water-pot of the furnace, as is seen when we reckon what half a pint per thousand cubic feet means in the course of a day."[2]

When it is necessary to carry heat for a considerable distance or to warm large buildings or blocks of buildings from a central point, it will be better and more economical to employ hot water or steam as the heat-transmitting agent, on account of the high specific heat of the former and the great amount of latent heat held by the latter. "It is uneconomical to convey heated air any long distance, as the amount of heat conveyed per cubic foot of air raised to any practical temperature is so small and so easily lost in transit. On this account Morin considers the availability (of hot-air furnaces) to be limited to a horizontal range of 40 or 45 feet from the heating apparatus."[1]

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[1] Most modern furnaces have a water-pan from which evaporation may take place freely into the warmed air, but the filling of this, when left to servants, is so often neglected that connection with the water-supply of the house by means of a float-valve or automatic cut-off would better serve to secure a constant supply.

[2] Harrington, pp. 420, 421.

An equal quantity of heat, viz., 1 thermal unit, is required to raise 1 pound of water or 50 cubic feet of air 1 degree F., and accordingly water will carry more than four (4.21) times as much heat as an equal weight of air at the same temperature. "Further, a greater effect is produced when water, in the form of steam, is made the carrier of heat, because 1 pound of water vapor at 100° C. (212° F.) will, in condensing to form boiling water, give off sufficient heat to raise the temperature of 5.36 pounds of water (or $4.21 \times 5.36 = 22.5$ pounds of air) from 0° to 100° C. (32° to 212° F.)."[2]

Hot-water heating may be by either the low-pressure or the high-pressure system. In the former, large pipes (generally 4 inches in diameter) are used, and, the system being open to the air at its highest point, the temperature of the water can never be much above 212° F. at any part of the system. The water circulates comparatively slowly, but, owing to the large volume, conveys much heat from the furnace to the places where it is needed. The high-pressure system employs small but very strong pipes, the water being completely enclosed from the outer air, wherefore it attains a high temperature, usually about 300° F., and circulates rapidly. The necessary expansion is provided for by larger pipes partly filled with air at the top of the circuit. The maximum temperature is regulated by the proportion of pipe, usually one-tenth, exposed to the fire. Either of the hot-water systems, but especially the low-pressure one, requires careful planning and setting to maintain evenness of circulation; and when the latter is complicated, as by many radiators at various levels, or where a number of circulations have to be supplied from the same boiler, it may be very difficult to maintain an even head and an equable distribution of heat in all. "If properly constructed and the heating planned for when the house-plans are made, this hot-water system is probably the most economical, both in fuel used and repairs demanded."[1]

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[1] Stevenson and Murphy, vol. i., p. 117.

[2] Notter and Firth, Treatise on Hygiene, p. 231.

Steam-heating methods are usually quite satisfactory, not only because of the large quantity of heat carried, but also since a rapid circulation is readily maintained even under adverse circumstances. The size of pipe used will depend on the extent of the distribution, but the calibre of the radiator should always be considerably larger than that of the supply-pipes in order to favor condensation and the consequent liberation of latent heat, and every facility should be provided for the speedy return of the condensed vapor to the boiler. Care must also be taken to prevent the condensation occurring in such a way as to cause obstruction to the flow of the steam and the disagreeable thumping and noise that result.

With either steam-heating or hot-water heating the direct, the indirect, or the direct-indirect method of radiation may be used. Of these, the *direct* method—that is, where the radiators are placed in the rooms to be warmed—is most commonly employed in dwellings and other buildings of moderate size; but it is open to the objections that in itself it does not bring about a sufficient change of air, that the necessary inlets and outlets for the latter are rarely provided, and that when present they are independent of the heating system of the house. Of course, these objections are wanting when the direct is combined with the indirect method, or when a plentiful supply of pure air is brought from without and is warmed by being made to pass through the radiators (either open or enclosed in boxing) before diffusing through the room. In the *indirect* method the radiators are placed outside of the room in suitable and convenient enclosures, into which fresh air is brought from out-of-doors, and from which the warmed air is conveyed by suitable conduits to the respective rooms above. The *direct-indirect* method locates the radiators in the room, but encloses them and provides inlets to the boxing from without, so that the entering air must pass over the heating surface and be warmed before entering the room. If properly arranged, both the indirect and the direct-indirect methods should furnish good and ample ventilation, the incoming warm air pushing the used air of the room ahead of it through the various openings in the walls of the room. Safety-valves on steam boilers lessen the risk of explosions, and automatic thermo-regulators make it possible to maintain a practically even temperature throughout the house or building at all times. But there must be some arrangement for supplying additional moisture to the warmed air, just as with hot-air furnaces, for, contrary to the opinion of many, neither the steam nor hot-water systems increase the atmospheric humidity.

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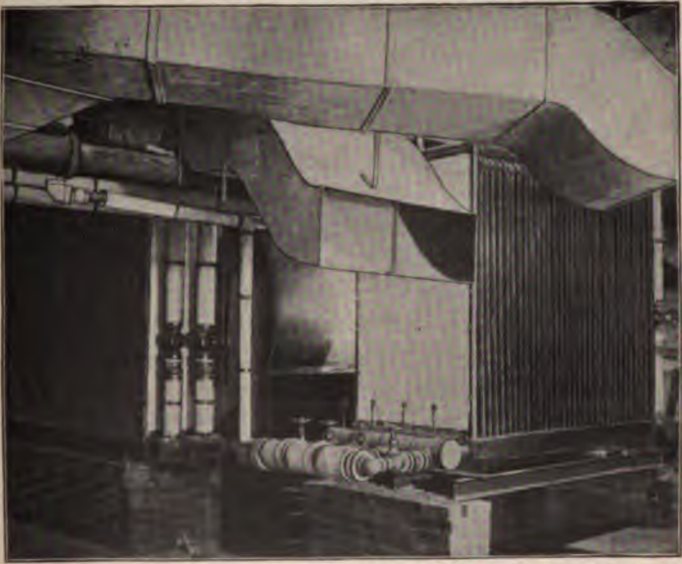
[1] Coplin and Bevan, p. 325.

In the clinical amphitheatre of the Medico-Chirurgical College of Philadelphia the indirect system is employed, the details being as follows: The out-door air is brought from near the roof-level through a large shaft into the cold-air room, where it is moistened by a spray and whence it passes through a dust-filter, consisting of a double layer of fine wire-gauze. Thence it passes through tempering radiators (to raise the temperature partially) into the revolving fan, driven by its own engine, whence part passes through a second and larger radiator to be further warmed, and part below the latter, the two currents again uniting and, after mixing, passing through the flues into the amphitheatre above. In this the temperature is regulated by a thermostat, the latter governing a damper (not shown in Fig. 24) which always permits the

FIG. 24.



Steam radiators and blower used in warming the clinical amphitheatre of the Medico-Chirurgical College of Philadelphia by the indirect system. (The casing of the radiators is not yet applied.) Tempering radiator at left; warming radiator at right; casing of fan between.

same volume of air to pass into the flues, but controls the respective proportions of heated and tempered air, so that the mixture practically does not vary in temperature. In this way 900,000 cubic feet of air at a fixed temperature can be supplied per hour. For the private operating-rooms the system is the same except that the tempered and the heated air are not mixed, but each is carried by separate flues to double registers in the operating-rooms. In this way each operator can have the temperature that he desires in his room at any time.

Another excellent method is to use the plenum system, and to warm or "temper" the incoming air, either before or after it passes through the driving fan, to a temperature just below that desired in the rooms, in which steam or hot-water radiators are suitably located. The air will then pass from the inlets more or less directly to the radiators and be additionally warmed by them before rising above the lower levels of the room. In this way the circulation and distribution of the fresh air are much improved, and there is less likelihood of it going directly from inlets to outlets.

To determine the amount of radiating surface needed for any room, we must multiply the volume of air to be heated per hour by the difference between its temperature in degrees Fahrenheit before and after warming, and divide this product by 50, the quantity of air in cubic feet raised 1 degree F. by 1 thermal unit. This will give the number of heat-units required to warm the air. Then this quotient must be divided by the difference between the temperature of the radiating surface and that of the air when finally warmed multiplied by 1.75, the number of thermal units given off per hour by 1 square foot of hot-water or steam-pipe for each Fahrenheit degree of heat it loses. This will give the area of hot-water or steam-pipe required to warm the given volume of air. Thus, to warm 6000 cubic feet of air per hour from 20° to 70° F. will require $\frac{6000 \times (70 - 20)}{50} = 6000$ heat-units, and if the surface of the radiator be 200° F., $\frac{6000}{(200° - 70°) \times 1.75} = 26.37$ square feet will be the area of radiating surface required. To this must be added at least one-half square foot for each square foot of window glass and for each square yard of outer wall exposed.

## CHAPTER V.

### WATER.

NEXT to air, water is the most important of all substances necessary to human life. While it has been often demonstrated that man may do without food for a considerable length of time, even for several weeks, he can probably not survive much more than ten days without water. Not only must one have sufficient to supply the internal wants of the body and to replace that lost by excretion, evaporation, and respiration, but from a sanitary point of view a plentiful supply is also needed to maintain cleanliness of bodies, clothing, and dwellings, and oftentimes to remove sewage, excreta, etc., from the vicinity of inhabited places. The care of furnishing water in abundance and of maintaining its purity is therefore entirely within the domain of the physician and the sanitarian.

Before inquiring into the sources whence we obtain the water that we use, it will be well to know what amount is required by the body for its daily needs and how much for other necessary purposes, so that we may be able to judge not only whether a given source furnishes pure water, but also whether it gives a sufficient supply of it.

The average adult should take from 70 to 100 fluid-ounces per day for nutrition and internal needs of the body alone—about one-third of this being a component part of the food and the rest being taken in as drink. The writer is of the opinion that the average person does not imbibe enough water for the most healthful action of his tissues and organs. Certain it is that in most cases the plentiful use of a good drinking-water not only greatly favors the body metabolism, but also materially assists in the flushing out and carrying away of the various wastes and excreta of the system.

In addition to this we must supply a sufficiency for cooking and for washing the food, body, clothing, household utensils and parts of the house itself, and to remove the household waste and sewage through the drains and sewers provided for that purpose. Cleanliness is an essential requisite for the preservation of health, and cleanly habits should be inculcated among all classes of people and every facility provided for removing filth of all kinds from persons, clothes, and dwellings. This, of course, cannot be done without an abundant supply of water.

Experience shows that about 25 gallons per head per day should be furnished for the above purposes, and as the quantity used by domestic animals, manufacturing establishments, municipal needs, etc., must be added to this, 50 gallons or even more per capita should be the daily quota wherever it is at all possible. And though a supply that permits of excessive waste may be inadvisable and expensive, both in its provision and on account of increasing the cost of carrying it away after use, it is always better to have too much than too little, and the disadvantages of too scanty an amount are much greater than those of one too large.

It should be stated, however, that most foreign cities are supplied with much less water per capita than is apparently needed by the municipalities of this country, and yet they seem to have an abundance for all necessary purposes and the requirements of public health. For instance, London, with a population of over five millions, has an average daily supply that but slightly, if at all, exceeds that of Philadelphia with one-fourth the number of inhabitants; while Berlin, which has about the same population as Philadelphia, had in 1893 an average daily supply of filtered water of only 18.4 gallons per head, all of which was sold to consumers by meter, but to which must be added considerably more that was from wells and other sources and was exclusively used for manufacturing purposes, running machinery, etc. Undoubtedly the quantity wasted in many of the cities in this country is excessive, and the cost of supplying that part of the total quota would go a long way toward improving and rendering pure and safe the remaining part that is absolutely needed. Whether the compulsory use of water-meters is the best way of bringing about an improvement in this respect remains to be determined; but it is also a question whether our larger cities, with rapidly increasing populations, can afford to continue to use the means necessary to purify the enormous and increasing quantities of water daily supplied to their respective consumers.

As only a small portion of the quantity indicated above is required for the internal needs of the body, it has been suggested that two kinds of water be furnished to each dwelling—one for drinking and cooking purposes and for the washing of the body, to which especial attention as to purity should be given; and another kind for all other purposes, its composition and purity being disregarded, excepting possibly as concerns the hardness. This would enable the authorities to furnish a water purer than usual for those needs wherein purity is of the greatest importance, and would obviate the necessity of furnishing pure water abundantly for *all* purposes; but the scheme would necessitate a double set of reservoirs, mains, distributing apparatus, etc., thus materially increasing the cost; and there would always be present the danger of the careless or ignorant using the impure water for bodily needs, thus increasing the risks and bad results that we wish to avoid. Therefore, wherever there may be an abundance of pure water for all personal and domestic purposes, if the authorities but take pains to furnish it, it will be best to have but one supply in dwellings, and this as pure and abundant as money and the ablest sanitary skill can make it; though there may be little or no objection to using a different water for factories, stables, city functions, etc.

As to the question of supply through meters, it may be added that the suggestion has been made that the regular charge for water begin only after a certain specified amount per month per capita or per household has been furnished free or at the lowest possible cost, thus doing away with the objection that those who need the water most for personal and sanitary uses would be tempted to economize too much if they had to pay for all they consumed. Whether a city could afford to do this, would have to be carefully considered, and would probably depend largely upon local circumstances.

Another method is "to assess every owner of premises where water is used (and measured by meter) a certain moderate, but fixed, sum yearly, even though water used at the regular rate per thousand gallons does not call for so much charge." This sum would, of course, be considerably less than the rate necessary under the old method, and in itself would be an inducement to the introduction and use of meters.

Experience shows that meters greatly reduce the total consumption of water, since it is to the direct advantage of each consumer to check reckless waste on his own premises, which is otherwise neglected because it does not affect the yearly charge and cost of water to him. Meters, wherever used, seem to have materially reduced both the cost of water to the consumer and the cost of supplying it on the part of the city or other owners of the water-works. It may, however, often be advisable for the latter to own and control the meters, as do gas-companies.

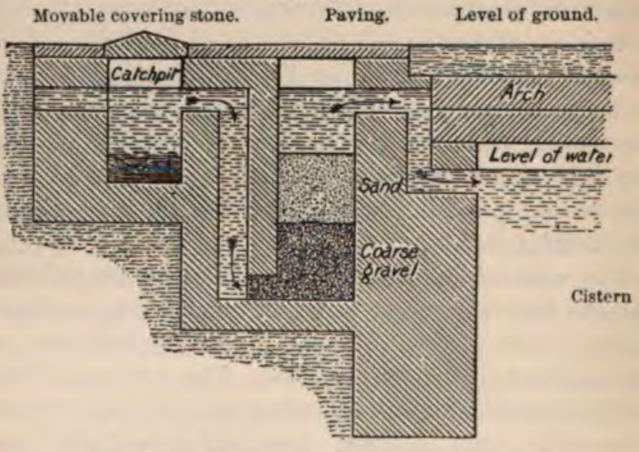
**Sources.**—Practically, all drinking-water has at some time or other fallen upon the earth from the atmosphere in the form of rain, hail, snow, or dew; but when we speak of its source we have reference rather to the immediate place or locality from which we collect it for use. The rain on reaching the earth is disposed of in three ways: part at once evaporates and goes back to the atmosphere, part flows off according to the slope of the ground and collects in pools and streams, and part sinks into the soil. The ratio which these three portions bear to one another depends on the time, place, character of soil, amount of rainfall, etc. Consequently, we may classify the sources of potable waters—as Leffmann does—as follows: *rain-water,* collected immediately as it falls in the form of rain, dew, snow, etc.; *surface-water,* collected in ponds, lakes, streams, etc., and in free contact with the air; *subsoil-* or *ground-water,* derived mainly from the rain- or surface-water of the district, but which percolates and flows through the subsoil and is therefore not exposed directly to the atmosphere; *deep* or *artesian-water,* which is separated from the ground-water of the district by one or more practically impermeable strata, and which accumulates at a considerable depth below the surface. Springs are the result of the outcropping of water-bearing strata below the level of the water-line in them, and furnish either subsoil- or artesian-water, according to the kind contained in the respective strata.

Rain-water is theoretically the purest at our command, but in reality it takes up many impurities from the air in its fall, especially in the neighborhood of human habitations and communities, and by the time it reaches the earth contains ammonia, nitrous and nitric acids, and, in towns, sulphurous acid, soot, many bacteria, and even microscopic plants. Moreover, and especially after continued dry weather, the collecting surface upon which it falls is apt to be covered with dust and impurities of all kinds, which, being taken up by the rain-water, tend to make it unfit for use. But if there be some arrangement for turning aside the first portion of the rain, it containing the most of the impurities, and if the remainder be filtered and stored in proper receptacles, the water may be of excellent quality.

The main objection, however, to the sole use of rain-water is that dependence is placed upon a very uncertain source, and one which is especially apt to fail when an increased supply is most needed. The average rainfall in Philadelphia is about 39 inches per year; in very wet years it is about one-third more, and in very dry years about one-third less than the annual average. Each inch of rainfall gives 4.67 gallons per square yard of area on which it falls, equivalent to 22,617 gallons per acre. Allowing 60 square feet of collecting surface per head, and estimating the loss by evaporation, etc., at 20 per cent., an annual rainfall of 30 inches would give only about 2 gallons per head per day, or just about sufficient for cooking and drinking purposes and none for the other needs of the household.

Rain-water may be collected from roofs or from a plot of ground paved for the purpose with slate or cement, and be led by proper conduits to a cistern. It should be filtered (Fig. 25) before passing into the cistern, while the cistern itself should be such as to give no unpleasant taste or injurious substance to the water, should be so situated that it will receive no rubbish or impurities and that the water may be kept cool, and should be cleaned regularly and sufficiently often to keep the water sweet and wholesome.

Fig. 25.



A simple filter for rain-water. (Notter and Firth.)[1]

As rain-water contains considerable carbon dioxide and other gases, its solvent powers are increased, and cisterns should not be lined with lead, copper, zinc, or iron, lest these metals be taken up by the water and produce harmful results. These remarks do not apply to the so-called rustless iron now much used; but galvanized iron should not be used, as it may give up zinc to the water. Cement should also be used in lining brick or stone cisterns instead of mortar, as the latter may add lime to the water and render it hard.

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[1] Fig. 25 illustrates a filter for an underground cistern. One of similar construction can be readily made for cisterns above ground, the latter being always preferable.

Underground cisterns for storing rain-water should be avoided where possible, since they are liable to soil-air or sewage contamination unless absolutely air- and water-tight. Nor should the overflow pipe from a cistern open into a soil-pipe or sewer-pipe or drain, but always into the open air, since water is very prone to absorb the various gases with which it comes in contact and the sewer-air may readily contaminate the entire contents of the cistern.

Rain-water is especially valuable for cooking and washing on account of its softness, water being called "hard" when it contains an excess of the salts of calcium or magnesium in solution. Hardness due to the presence of calcium bicarbonate is said to be *temporary*, because it disappears when the water is boiled, one molecule of carbon dioxide being driven off by the heat and leaving the insoluble calcium carbonate behind. Hardness due to the other salts of calcium and magnesium is called *permanent*, because it is not removed by boiling. In cooking with water temporarily hard the chalk is precipitated upon the sides and bottom of the vessel, and, being a non-conductor, prevents the passage of heat and thus wastes fuel.

Hard water may also prevent the proper softening of certain foods, such as peas and beans, in cooking. In washing and laundry work the calcium and magnesium salts unite with the fatty acids of the soap and prevent the formation of a lather; for instance, one grain of chalk destroys the efficiency of about eight grains of soap. As we do not call a water hard unless it contains more than ten grains of chalk or its equivalent per gallon, and as rain-water rarely contains more than one-half grain per gallon, it is easily understood why the latter is so valuable in the kitchen and laundry.

A water-supply taken from rivers or smaller streams not polluted by the refuse and sewage from towns, factories, or cultivated farm-lands higher up the stream, may be fairly pure and safe to use. The best water of this kind will be from hilly and uninhabited, uncultivated tracts, with many small streams fed by constant springs and uniting to form rapid creeks and rivers. Such water may be tinged slightly with vegetable or mineral matters, but in general such coloration is harmless. For storage, dams may be thrown across convenient valleys, thus impounding the water and at the same time exposing it to the oxidizing and aërating influence of the atmosphere and allowing the solid impurities to settle to the bottom. Small lakes or ponds may be utilized to add to supplies of this kind, provided they be not stagnant nor have much decaying matter along their banks.

On the other hand, water from a stream which has received the sewage from a village or town of any size, or the refuse of factories, or the drainage from large tracts of cultivated land, should be considered as at least suspicious. River-waters are generally hard and may contain any of the minerals in the soils which they drain or over which they pass; but the great danger is from impurities of animal origin poured into them along their course.

It is not safe to depend altogether on the self-purification of sewage-contaminated rivers, as was formerly done, though a considerable portion of the sewage and filth undoubtedly is removed, part by oxidation by the air in the water, especially in streams flowing over dams, rapids, etc.;

part by subsidence or deposition along the banks; part by fish and animalculæ, and much by the myriads of saprophytic bacteria which such waters contain. If no additional pollution is added, what is left unchanged by the above purifying agencies is still further diluted by the supplies of pure water that every stream receives from springs along its banks and in its bed and from tributary streamlets, so that, though the water may never be so pure as it was originally, it may possibly become or, by proper filtration or treatment, be made a safe and usable water. But where the proportion of filth exceeds a certain percentage, and especially where sewage is being constantly added, the contained oxygen is rapidly used up and oxidation ceases, fish and animalculæ cannot live in the water for lack of sufficient oxygen, and though the heavier and larger particles of the sewage sink to the bottom or stick to the sides, they are stirred up and set in motion by any increase in the velocity of the current. The only remaining agents active in the destruction of the foul matter are the bacteria, but in themselves they are often insufficient for the task, and the water thus polluted is unsafe for use.[1]

The greatest danger from sewage contamination, however, is that it may at any time add to the water the germs of infectious disease, which, multiplying rapidly and not being surely removed or destroyed by the ordinary agents or methods of water-purification, greatly increase the risks to health. It often fortunately happens that, owing to the hostility of the saprophytic bacteria of the water, or to the presence of certain chemical substances, or to other unfavorable conditions, as of temperature and the like, these pathogenic organisms do not multiply so rapidly as they otherwise would, and are therefore not plentiful enough to do much harm. But, as it never can be certainly told when a water so contaminated becomes safe for use again, and as the population of most towns and their consequent sewage production are constantly increasing, while the quantity of water in the receiving streams remains about the same or is diminishing from year to year, the use of such water should be avoided if possible, or, if it must be used, it should be purified and made reasonably safe by the most scientific and efficient means and methods available.

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[1] According to the report of the Rivers Pollution Commission some years ago, no stream in England is of sufficient length to purify itself satisfactorily of the sewage contamination it is liable to receive. On the other hand, it is only fair to state that, according to a recent report (April, 1903) of the Commissioner of Health of Chicago, very careful and extensive investigation shows that the large quantity of sewage from that city discharged into the Illinois River has entirely disappeared long before the latter empties into the Mississippi.

Water from large fresh-water lakes will be of the best quality, provided it be taken from a point sufficiently distant from the shore to escape all danger of sewage contamination. Chicago apparently lowered the mortality percentage from typhoid fever from 7.2 in 1891 to 2.1 in 1895, and 3.2 in 1896, by preventing as far as possible the discharge of sewage into Lake Michigan and by taking the water-supply from the lake at a minimum distance of one mile instead of 1400 feet from shore as formerly. Water from small lakes or ponds, and even from storage reservoirs, may become offensive to taste and smell through the growth in them of minute vegetable organisms, such as the algæ, though it is not known that these are prejudicial to health.

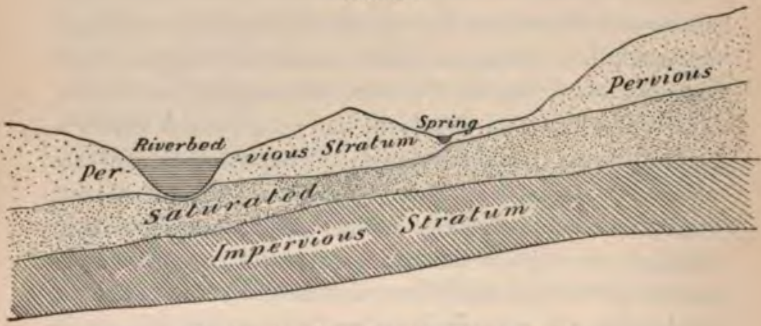
Ordinarily, water loses much organic matter as it percolates through the soil, but takes up considerable carbon dioxide from the soil-air, which increases its solvent powers so that it may also dissolve some of the mineral constituents of the soil through which it passes. When these mineral substances become so great in amount as to give the water a decided taste or medicinal properties, we call it a mineral water; but when the inorganic matter does not render it objectionable to the taste or too hard, the water, whether subsoil or artesian, will usually be quite safe and usable in so far as the mineral matters are concerned.

Attention has already been called to the pollution of the soil. How, then, can the water in passing through it lose its organic contents and become pure? Partly by mechanical filtration, but mainly through the combined action of the saprophytic bacteria and the oxygen of the soil-air, which rapidly convert the organic impurities, both suspended and dissolved, into simpler and harmless end-products. The substances of vegetable nature are ultimately resolved by these agencies into carbon dioxide, water, etc., while those of animal origin and containing nitrogen give rise to the various ammonia compounds, or may be further oxidized into nitrous and nitric acids and their salts, all entirely harmless in the proportions in which they are found in the percolating ground-water, but all of great value as nutrients for the higher plant-life of the soil.

The rate of percolation has much to do with the completeness and perfection of this action, for ample time must be had for the organic decompositions to occur. Therefore, anything that retards the downward flow of water favors its purification, and anything that increases its movement decidedly affects for the worse its ultimate quality and character.

The importance of this biologic soil action can scarcely be overestimated, and the student should endeavor to appreciate not only the bearing which it has in the great scheme of nature's adaptation of means to ends, but also the importance of our utilization of it in the artificial purification of our environment and in the disposal of waste matters. We must understand, however, that for every soil only a definite amount of work can be accomplished by the agencies mentioned and under the conditions existing at any given time. In other words, there is here also a *limit of permissible impurity*, and if this limit is exceeded, the conditions become unnatural, the bacterial and chemic action is inadequate, and the descending water is not thoroughly purified as it percolates through the overcharged soil.

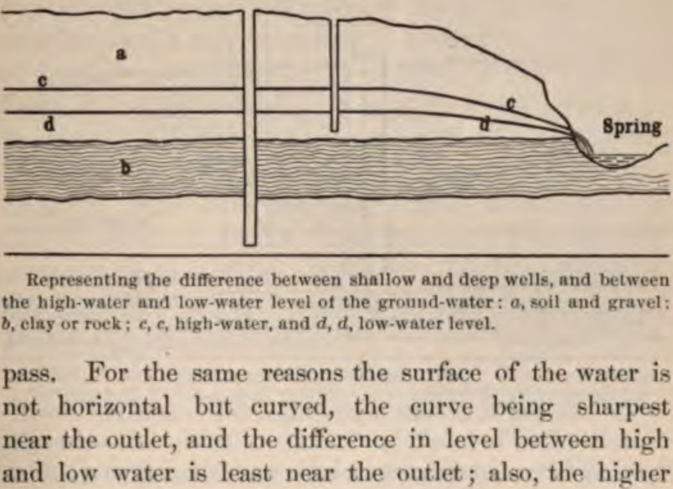
FIG. 26.



Outcropping of water-table. (HARRINGTON.)

The subsoil-water slowly sinks through the ground until at some level or other it reaches an impermeable stratum, where it is retained in natural basins or escapes at some outcropping of the stratum below the water-level, thus forming a spring. (Fig. 26.) The level of the water in these underground reservoirs is constantly changing according to the season, rainfall, discharge from springs, etc., though ordinarily the variation for any given place differs little from year to year. It is from wells sunk to these water-bearing strata and from springs that water is obtained for the majority of people who do not live in towns or cities supplied by water-works. These underground bodies of water are in constant motion toward one or more outlets at more or less distant points, but the currents are usually quite sluggish owing to the friction and capillary force of the particles of soil through which they pass. For the same reasons the surface of the water is not horizontal but curved, the curve being sharpest near the outlet, and the difference in level between high and low water is least near the outlet; also, the higher the level the greater the fall to the outlet and the greater the discharge. (Fig. 27.)

FIG. 27.

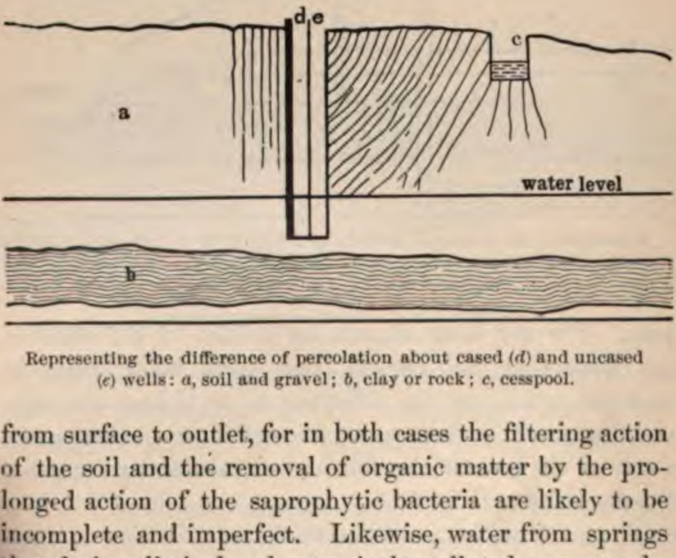


Representing the difference between shallow and deep wells, and between the high-water and low-water level of the ground-water: *a*, soil and gravel; *b*, clay or rock; *c*, *c*, high-water, and *d*, *d*, low-water level.

The outflow from most continuously flowing springs represents the percolation through and drainage of such a comparatively large area that it is not probable that any considerable proportion of this area will be excessively polluted, nor that the percolate from any and all over-polluted parts of it will be so concentrated and charged with harmful impurities that the thoroughly purified water from the remainder of the area will not be sufficient to dilute it sufficiently to eliminate all danger to health from its use. Consequently, springs are to be ranked among the best and safest sources of natural waters, and general experience sustains the judgment.

But the remarks regarding the purity of spring-water do not hold good for water from ordinary shallow wells—provided they do not pass through an impermeable stratum—or from springs where the water passes almost directly from surface to outlet, for in both cases the filtering action of the soil and the removal of organic matter by the prolonged action of the saprophytic bacteria are likely to be incomplete and imperfect. Likewise, water from springs that drain a limited and extensively polluted area may be seriously contaminated, and unsafe to use.

FIG. 28.



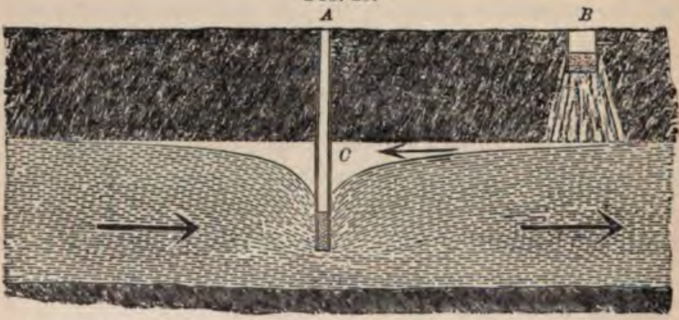
Representing the difference of percolation about cased (*d*) and uncased (*e*) wells: *a*, soil and gravel; *b*, clay or rock; *c*, cesspool.

Especially about human dwellings, where wells are commonly located for the sake of convenience, are filth and pollution likely to be carried into the water, for sewage and dirt of almost every kind accumulate in constantly increasing quantity in the soil about a house, and always tend to exceed the limit of permissible impurity. There is also the ever-present danger of the water receiving the specific germs of disease from the human wastes of the household, no matter in what condition the surrounding soil may be.

Owing to the lessening of lateral resistance the surface-water passes rapidly and almost directly into the well (unless the wall of the latter be made water-tight to almost the full depth), and may carry with it solutions of all the impurities polluting the soil about the mouth; and as wells drain a very considerable area—Parkes says one, in ordinary soils, whose radius is equal to four times the depth of the well—there are few wells about which such an area is not subject to dangerous pollution. (Fig. 28.) Moreover, the influence of pumping or other sudden withdrawal of water from the well is even more important, since it extends a distance from 15 to 160 times the temporary depression of the water-level, and impurities may thus be drawn into the well which ordinarily would tend to flow away from it. (Fig. 29.)

Excepting the bacteria, which pass freely through almost all soils when resistance to the water-current is markedly diminished, only such portions of the pollution as can be dissolved may reach the water in the well; and it is a fact that many waters thus polluted are sparkling and clear, with a pleasant taste and no bad odor, so that any suspicion as to their real character may be wanting. Moreover, even though specific disease germs be absent, there is always danger that the contamination may become so concentrated as to produce serious results, and this may occur in various ways: (*a*) the well may be so deep or the character of the soil such that in ordinary weather the liquid passing through the soil is so purified that it imparts no harmful properties to the water; but if the soil is being continually infiltrated with dangerous impurities, and if at length heavy rains or continued wet weather supervene, there may be more and more of these impurities dissolved and carried into the well until the proportion of harmful matter in the water passes the safety-line, and as a result there is marked illness or increased predisposition to disease among those using the water; or (*b*) in continued dry weather the ground-water may be lessened to such an extent that the impurities that were formerly well diluted become sufficiently concentrated to cause sickness, even though there be no unusual pollution of the soil about the well; or (*c*) the water-level in the well being suddenly or persistently lowered, a greater area is drained and additional collections of sewage may flow into the well. (Fig. 29.)

FIG. 29.

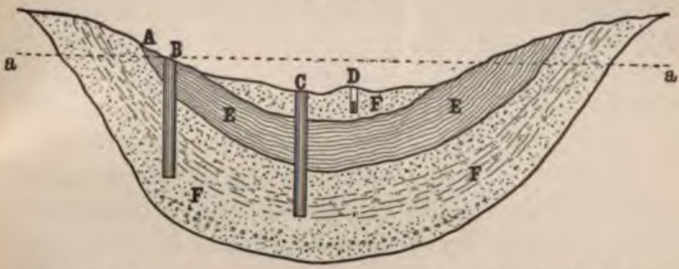


Showing depression of water in shallow well caused by pumping: *A*, well; *B*, cesspool; *C*, underground water-curve. (After FIELD and PEGGS.)

Deep wells are those which pass through an impermeable stratum, and so do not get their supply from the subsoil-water. The relative depth of two wells is no exact criterion as to their classification, as the shallower one may really be a "deep" one and the deeper a "shallow" one, according to the presence or absence of the *impermeable* stratum. Artesian wells are very deep wells, piercing one or more impermeable strata.

Sometimes the water rises and flows out of the mouth of a deep well, in which case the supply is drawn from a water-bearing stratum between two impermeable ones, and which has its only outcroppings higher than the top of the well. (Fig. 30.) The water accumulates in this natural reservoir above the level of the well-mouth, and is forced out when an opening is made through the uppermost impermeable stratum. Deep well-water is apt to be of much better quality than that from shallow wells, since it usually represents the total percolation from a very large extent of ground surface, in comparison to which the combined areas and amount of pollution within its limits are insignificant, the possible impurities in the water being

FIG. 30.



Representing the spontaneous flow of deep or artesian wells, B and C: a a, water-level in deep pervious strata, F F; A, intermittent spring at outcropping of F F above impermeable stratum, E E; D, shallow well in upper pervious strata. (WILSON.)

consequently reduced by dilution to much below the danger-point. It is for the same reason that there is such a difference in the quality of spring-water and of that from most shallow wells. Though the two waters seem to have a common source, one is the composite water of a large district, of which the average impurity or contamination per unit of surface may be infinitesimal; the other is mainly the special percolate from a limited area, which is, for the reasons given, particularly liable to be highly and dangerously polluted.[1]

Artesian or deep well-water will also likely be very free from organic matters, but possibly heavily charged with mineral salts. Should these latter not be present, the water will probably be of excellent quality; though if the well be very deep, it may be too warm for immediate use as a potable water.

Frequently well-water, and that most often from shallow wells, is the only kind available, especially in country districts. In such cases care must be taken that impurities are kept out of the well by all possible means. If this be done, water may often be had of excellent quality. The area about all wells should be kept clean, and the well should be as distant as possible from any source of contamination, especially if the latter be a constant one. Wells should be walled or cased, shallow wells to below the water-level and deep wells to the first impermeable stratum if possible, in order to cause the water to percolate through as much soil as possible before entering the well, in this way checking the rapidity of its descent and prolonging the biologic action of the top-soil.[1] Wells should also have a properly constructed curb, to keep out splashings and drippings of muddy or dirty water.

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[1] Of course, the water in shallow wells, as in others, is being continually changed by the onward movement of the underground current; but where this is slow in comparison with the percolation from the surface, the impurities of the latter will be in excess in the well-water.

We must not forget that wells drain a large area. As the ground-water has a constant movement in the direction of natural outlets, the well should be so located that the current flows *from* it toward any near-by cesspool or other source of pollution. The direction of the underground current can generally be determined by noting the location of the nearest spring or water-course, by observing the dip of the underlying strata, or by digging holes at equal distances about the well and dissolving salt or an aniline dye in them in turn, and testing the water from the well after a time for the salt or color. If a well be much deeper than a neighboring cesspool, it may drain from the latter, even in opposition to the ground-water current, especially if the water in the well be suddenly lowered. Again, dangerous impurities have been carried into wells from long distances through fissures or crevices in rock. Harrington cites the case of a well which, "bored 500 feet into red sandstone, drained, through fissures, all the shallow wells in the vicinity. These being of no use as wells, were then utilized as cesspools, and draining again through the fissures, caused the well to become so foul that it had to be abandoned."

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[1] As the saprophytic and nitrifying bacteria are only found normally in the first few feet of top-soil, where the conditions are favorable to their existence and growth, we cannot expect to have any further action by them after the water reaches its underground level and begins to move toward its outlets. Nor will there be any filtration in this onward progress, for that has been accomplished in the upper layers. It is for this reason that the filtrate from cesspools and similar pits is not organically purified, but is especially obnoxious and dangerous as it traverses the soil, for the bottoms of such pits are usually below the biologic level, and there is also in them a lack of the oxygen necessary to maintain the action of the nitrifying bacteria.

The water from the well should be frequently tested for chlorides and nitrates, these indicating sewage contamination, and this should be done especially after heavy rains and also when the water in the well becomes low. The taste and odor of the water should also be noted after standing for a time or on being heated. Some other sources should be sought whenever such tests show contamination or when there are cases of infectious disease near at hand. Boiling the water and filtration are always to be recommended whenever there is the least suspicion as to impurity or infection.

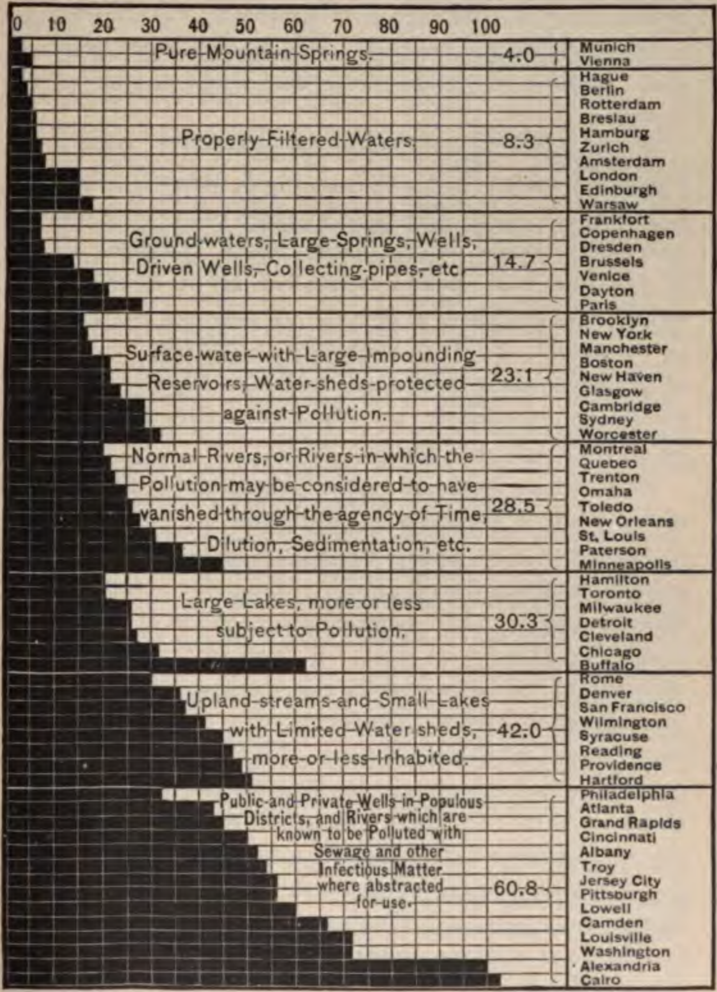
Shallow or subsoil wells in thickly settled towns should not be used to supply drinking-water or cooking-water, as the soil is always more or less saturated with filth and sewage, and it is practically impossible in such places to locate a well which will not be in constant danger of receiving harmful impurities from some source or another.

The decision as to the quality of any water must in each case be determined by all the circumstances available which relate to it, and these should all be thoroughly investigated before rendering an opinion, as some of them may counteract the others. However, other things being equal, the value of a water will probably be in accord with the following table:

| | | |
|---|---|---|
| Wholesome | 1. Spring-water, | Very palatable. |
| | 2. Deep well-water, | |
| | 3. Water from unpolluted streams, | Moderately palatable. |
| Suspicious | 4. Stored rain-water, | |
| | 5. Surface-water from cultivated land, | Palatable. |
| Dangerous | 6. Sewage-polluted river-water, | |
| | 7. Shallow well-water, | |

A good potable water should be perfectly clear, free

FIG. 31.



Showing death-rates from typhoid fever in 1894 in sixty-six cities, grouped according to the quality of their drinking-water. (Reproduced with the permission of the author, Mr. James H. Fuertes, and of the Association of Civil Engineers of Cornell University.)

from odor or taste, cool, well aërated and, if possible, soft or with only a mild degree of hardness. Circumstances must determine the amount of dissolved matters permissible; what is an excess in one case might not be so in another.

We may also classify waters as follows: 1. Pure and wholesome water. 2. Usable water. 3. Suspicious water. 4. Dangerous water. (See chart on page 165.) Pure waters and usable waters may be used without filtration; those of the third class should be filtered before distribution, and also at the house before use, if possible, and a purer source sought or all sewage-pollution prevented. Those of the fourth class should not be used at all except when absolutely unavoidable, and then only after purification by all the means at command.

Inasmuch as most large cities must from necessity furnish a water of the second or third, and occasionally even of the fourth class, such water should be purified as much as possible before distribution by storage for a time in settling reservoirs and by some effective system of filtration, combining these with chemical treatment if necessary. As much of the organic matter is oxidized, and many of the pathogenic bacteria are destroyed by saprophytes and other causes while the water is standing in the settling reservoirs, and as properly constructed and well-managed filters are even more efficacious to this end, a water originally suspicious or worse may often be made usable by the above means properly employed. Not only must the storage reservoirs and filtering apparatus be kept clean and in good working order, but care must also be had that the distributing apparatus does not permit soil-air or sewer-gas or sewage to be drawn in through leaks in the mains at times when the flow is intermittent, and that lead pipes are not used for conveying drinking-water if the character of the water is such that it acts on that metal.

**Diseases Caused by Impure Drinking-water.**—A polluted water may carry the organisms of infectious diseases, or it may produce or favor the development of diseases which are not due to specific germs. In addition to these, and of at least equal importance from a sanitary point of view, is the depressed state of the system that the habitual use of impure drinking-water causes, and the predisposition to disease that ensues. By the faculty of accommodation and through long habit a community may become so protected against an impure water as to manifest no striking symptoms, while strangers may be seriously affected by it; but even in such a case the condition of those habitually using the water will probably be more or less depressed and not that of perfect health.

The non-infectious diseases likely to be caused by impurities in the drinking-water are primarily those affecting the alimentary tract, as dyspepsias, diarrhœas, and other disturbances having their origin in severe gastric or intestinal irritation. So, also, impure water, even though it does not contain the actual germs, may have much to do in bringing on an attack of typhoid fever or specific dysentery by so irritating the intestine as to make it especially receptive to the cause of the disease when introduced from another source.

Large quantities of the sulphates of calcium and magnesium are thought to have special influence in causing dyspepsias, with loss of appetite, pain at the epigastrium, etc. An excess of iron in water is also prone to produce constipation, headache, loss of appetite, and malaise. Goitre and the formation of vesical calculi are each supposed to be due to mineral or inorganic impurities, though the true relation of impure drinking-water to these diseases is still unsettled. "It has long been a popular opinion that drinking lime-waters gives rise to calculi of the oxalate and phosphate of calcium," and the "opinion that impure water is the cause of goitre is as old as Hippocrates and Aristotle." Further study of the principles underlying the treatment of goitre with glandular extracts may make it easier to determine whether impure water has a causative influence in the production of this disease.

Diarrhœa may be caused by any of the following impurities in water: suspended substances of any kind, but especially those of fecal origin; dissolved animal, vegetable, or mineral matters, and fetid gases. The diarrhœa produced by any of these contaminants may be so severe as to simulate true dysentery and cause doubt as to the diagnosis.

Certain metals may be taken up from the earth's strata, or from the lining of cisterns, etc., and may produce their characteristic toxic symptoms in the system. Lead is one of these metals, and it will be well to note here the waters that are especially apt to take up this metal. Pure waters and those containing much oxygen act powerfully on lead, as do those containing organic nitrates and nitrites, especially ammonium nitrate. Waters containing carbon dioxide and the salts of calcium and magnesium and those free from absorbed gases act least on lead, and carbon dioxide seems even to protect lead by forming an insoluble carbonate on leaden surfaces, but water containing carbon dioxide may take up lead for a time from new pipes until the insoluble carbonate is deposited within them, and it has been shown that in some cases wherein cold water does not act upon the metal hot water will dissolve a small but appreciable quantity of it. Copper, zinc, and arsenic are also metals that may be taken up by certain waters, and that may cause serious results from the use of the latter. Lead is more easily dissolved if other metals are in contact with it, probably owing to electrolytic action. Lead should not be used for pipes nor to line cisterns unless suitable tests show that the water does not affect it, nor should any water be used in which the tests show more than one-thirtieth of a grain of lead per gallon.

Of the infectious diseases, germs of typhoid fever, cholera, and dysentery are usually carried into the system by the drinking-water, while the same is often true of scarlet fever, diphtheria, and kindred diseases, and possibly of malaria.[1] But, as with the impurities causing non-infectious disturbances, water containing disease germs may sometimes be used for a long time by those accustomed to it without the development of the specific malady, and it may only be after the system is weakened by excesses or other predisposing conditions that the disease manifests itself; or it may happen that only strangers and non-acclimated inhabitants incur the disease. It has been suggested that this immunity is probably brought about by the very gradual introduction into the body of the disease germs and their poisons, so that old residents are not susceptible to the small numbers or quantities of these which are sufficient to give rise to the symptoms of the particular diseases in newcomers.

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[1] For a long time the belief that malaria is very frequently, if not most often, transmitted by the drinking-water has been held by many sanitarians, and there has seemed to be much circumstantial evidence to substantiate this opinion. Comparatively recently, however, careful scientific investigation has proved that this disease can be and usually is due to direct inoculation by at least one species of mosquito, which acts as an intermediary host in the life cycle or development of the malarial organism (plasmodium malariæ), and some have gone so far as to say that the disease is probably only transmitted in this way. While admitting the force of these arguments and evidence, and accepting the mosquito theory, the writer, for the present at least, is not convinced that the drinking-water cannot and does not also sometimes serve as a means of transmitting the disease, either by acting as a carrier of the infected ova, larvæ, or dead bodies of mosquitoes, or by directly transferring the malarial organisms from what has long been considered to be their natural habitat—swamps and marshes.

Many instances have been recorded which practically prove the transmissibility of infectious diseases by means of drinking-water, and of these reference may be made to the epidemics of typhoid fever at Lausen[1] in Switzerland, and at Plymouth, Pa.;[2] of malaria on board the transport ship "Argo";[3] and of cholera in London.[4] The writer himself had an opportunity of investigating an epidemic of typhoid fever in a small village in North Carolina.[5] In this there were only four or five in about sixty cases which were not undoubtedly due to contamination of the subsoil-water by the infected excreta from the first case; and of four of the exceptions (which were in one family), the first was in all probability infected while in attendance upon sick neighbors, and the others by direct contagion. It was also shown that with the exception of these four the cases all developed directly along the lines of natural drainage leading from the residence of the original case—a boy, who came to the village sick with the disease—and that the latest cases to develop were those most remote from the starting-point of the infection.

Moreover, in most large cities of this and other countries the typhoid fever death-rate is accepted as the direct index of the character of the water-supply, and it seems to be a fact almost without exception that any marked improvement in the latter will be followed by an immediate and positive reduction in the former. (See chart on page 165.) The same may also be said to hold good in regard to diarrhœal diseases; while in eastern North Carolina there has been a marked reduction in the prevalence of so-called malarial fevers as a result of the efforts of the State Board of Health to persuade the people to substitute rain-water or deep well-water for the subsoil-water which was almost universally used a few years ago.

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[1] Pepper's System of Medicine, vol. i., p. 250.

[2] Rohé's Text-book of Hygiene, 2d edition, p. 63.

[3] Parkes' Hygiene, 8th edition, p. 64, and Rohé, p. 60.

[4] Rohé, p. 64.

[5] University Medical Magazine, May, 1892.

The ova of certain parasites, such as tapeworms or round-worms, may often be taken into the system with the drinking-water, and these upon developing may cause disturbances that may require more than the slight attention usually given to them. Any attack of convulsions in a child or other severe manifestation of reflex action should lead to the inquiry as to whether these parasites may not be present, and whether the water-supply has not been the source of invasion.

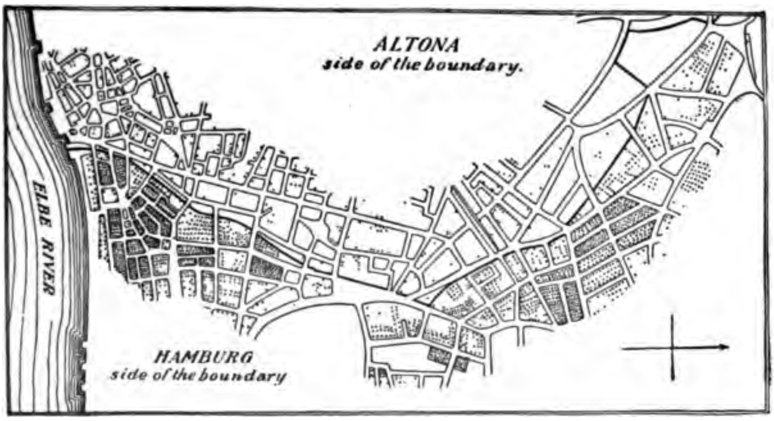
Regarding the foregoing remarks, Parkes makes the following statements: "1. An epidemic of diarrhœa in a community is almost always owing to either impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the last two causes, and if it extends over many families, almost certainly to water. But as the cause of the impurity may be transient, it is not easy to find experimental proof. 2. Diarrhœa or dysentery constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. 3. A very sudden and localized outbreak of typhoid fever or cholera is almost certainly owing to the introduction of the poison by water. 4. The same fact holds good in malarial fevers, and, especially if the cases are very grave, a possible introduction by water should be inquired into. 5. The introduction of the ova of certain entozoa by means of water is proved in some places, probable in others. 6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water-supply is given; and, apart from this actual evidence, we are entitled to conclude from other considerations that abundant and good water is a prime sanitary necessity." The statistics already given and those to come in later pages are confirmatory of the correctness of this last assertion, and sanitary authorities now realize that, in addition to the mortality from typhoid fever, the main cause of an increase in the death-rate from diarrhœal diseases is more often to be fairly attributed to a contaminated water-supply than to improper food or untoward temperatures. Even with respect to cholera infantum (which is generally supposed to be principally due to the influence of excessive heat upon the infant and its food) a number of epidemics show a closer relation to impure water-supply than to temperature-changes.

**The Purification of Water.**—Impurities in water may be either solid matters in suspension or dissolved substances, and may be organic or inorganic. Any turbidity is due to solid particles, and water free from these is clear, though it may be colored more or less deeply by dissolved matters. But a clear water may contain such solid bodies as bacteria, ova of parasites, etc., which are too minute to be seen with the naked eye. Whether harmful or not, all impurities should be removed in so far as is possible from all supplies of drinking-water. This may be done to a considerable extent with large volumes of water before distribution to consumers, and should always be attended to by the latter if the water is not already clean and within the limits of safety when they receive it. In fact, a large city at the present time can scarcely have a more important subject for consideration than that of obtaining the purest possible water-supply for its people. There will always be a tendency among many to allow matters to continue as they are or as they have been in the past, and a decided objection by others to incurring additional expense for what may seem to them only æsthetic reasons; but, no matter what may be the cost of providing a reasonable supply of pure water for any large city's personal and domestic uses, a very little consideration will show that such expenditure is true economy from solely a financial point of view, even though we ignore the misery and sorrow of the sickness and deaths that are due to the use of a polluted water.

As has been stated by the excellent authority quoted above, "the health of a community always improves when an abundant and pure water-supply is given." "The death of 3400 persons from cholera followed the temporary supply of unfiltered water by the East London Water Company in 1866, while the rest of London remained nearly free from the disease;" and in 1892 "Hamburg lost 8605 citizens from the same disease alone," regarding which "the health authorities found that the principal cause of this epidemic was the polluted water-supply,"[1] while the neighboring city of Altona, which used filtered water, was comparatively free from the disease.

Again, after the scourge of typhoid fever in Plymouth, Pa., in 1885, when there were 1104 cases and 114 deaths within a few weeks in a population of 8000 as a result of pollution of the water-supply by a single person, great care was taken to determine the exact cost of the "visitation" as some would term it. It was found that the actual expenditure for the care of the sick was $67,100.17; loss of wages by those recovering, $30,020.08; a total of $97,120.25, to which should be added a number of times the $18,419.52 that those who died were earning per annum when taken sick. How much cheaper in comparison would a protecting filter-plant have been! But overlooking special epidemics, and

FIG. 32.



Portion of the boundary line between Hamburg and Altona. The dots indicate cases of cholera. (HARRINGTON.)

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[1] Hazen, Filtration of Public Water-supplies, 1895.

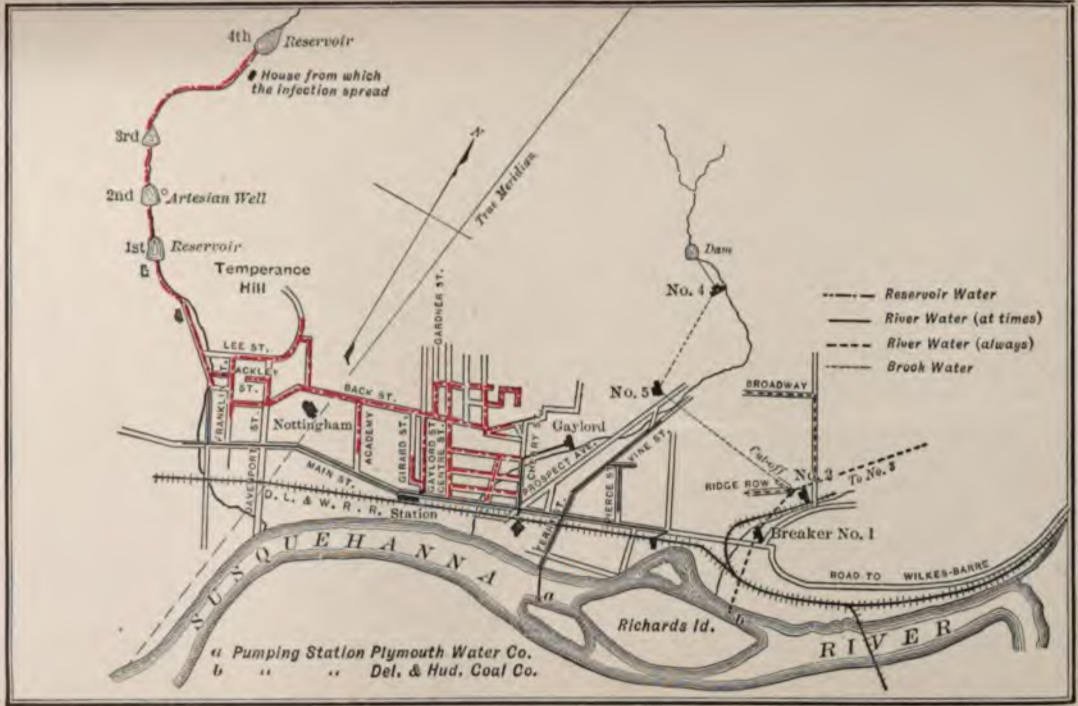

Chart of Plymouth, Pa., showing sources of its water and the distribution of the polluted supply (line in red). (Abbott.)

considering the *average* annual typhoid death-rates of our cities, we find that experience both here and abroad shows that with a pure water-supply a maximum death-rate from this disease is 25 per 100,000, and that any city may reasonably expect to secure even a lower rate by observing proper precautions. And yet only eight cities of over 50,000 population whose mortality returns were given in the United States Census Reports of 1890 had so low a figure. On the other hand, there were five cities of over (and two of less than) 50,000 that had 100 or more deaths per 100,000, all seven using unfiltered river-water. The remaining forty-one of those above 50,000 had rates varying from 26 to 98. Counting each death as a loss to the community of $5000—not an excessive estimate according to the finding of courts in cases of death by accident, and since most typhoid cases occur during the working age of from fifteen to fifty years—"the saving due to filtration" on the unnecessary deaths from typhoid fever "would have paid for the entire cost of filters in the first year they were in use" in the first seven of these cities; "in sixteen others, with an aggregate population of 3,717,560, filtration would have paid for itself in two years or less," and in "eighteen others with an aggregate of 3,238,617, filtration would have saved seven or more lives per 100,000 annually, and would have more than paid for the interest and cost of operating the filters."[1]

Lawrence, Mass., with a population of 44,654 in 1890, built a filter at a cost of $67,000, and saved enough lives, at $5000 per head, to pay for it within the first four months that it was in use, and had a reduction of almost 60 per cent. in the typhoid death-rate within a year.

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[1] Hazen, Filtration of Public Water-supplies.

In Chicago, when the similarly estimated loss from typhoid deaths in the city and suburbs amounted to over $10,000,000 in 1891, the abandoning of a shore inlet near the mouth of the sewage-polluted Chicago River in 1892 resulted in a reduction of 60 per cent. in the typhoid mortality during the following year. Albany, N. Y., is also said to have reduced the death-rate from this disease 70 per cent. since the installation of its filter-plant.

But it is only when one realizes that an increase in the mortality from any cause of only 1 in 1000 of population means 1000 additional deaths per annum in a city of a 1,000,000, that he can appreciate the meaning and the loss in capitalization to the municipality of the exceedingly high typhoid mortality that obtains in some of our large cities. At the valuation of $5000 per capita, and considering only the *excess* above the maximum typhoid mortality of a pure-water city, this death-loss in one city alone for several years has amounted to upward of $500,000 annually. Nor must it be forgotten that these figures do not include the cost of medical attention and nursing for the thousands who were sick, nor the loss of time and employment by those who recovered, nor do they consider the financial loss due to sickness and deaths from diseases other than typhoid fever that may be fairly attributed to polluted water-supplies. Can anyone doubt where true municipal economy lies, and is there not abundant opportunity for sanitary education and work in this direction alone for many years to come?

Purification before distribution may be by either or all of three methods: subsidence, chemical treatment, and filtration.

The first method consists in allowing the water to stand in large reservoirs until the greater part of the suspended matters have fallen to the bottom. If sufficient time be given, much of the organic matter, whether solid or dissolved, will be decomposed or reduced to simpler compounds by the action of the sunlight, oxygen, animalculæ, saprophytes, etc. Most of the bacteria also, especially the pathogenic species, will disappear either by sedimentation, by death from lack of favorable conditions, or on account of the germicidal effect of the sunlight. Consequently, a water originally quite impure may be much improved by this method alone, while if it is used in conjunction with and preliminary to filtration it will be additionally advantageous in that it reduces the cost of the latter by lessening the frequency and expense of cleaning the filters.

What the capacity of the reservoirs and the time of storage should be, depend on circumstances. If it is the only method of purification employed, and especially if the water is very foul, the longer the time of storage the better. Again, if the source of supply is variable in output or if it is liable to excessive pollution for limited periods, the capacity should be such, if possible, that water need not be collected during the emergency. On the other hand, if the water is to be subsequently filtered, the capacity of the reservoirs and time of storage need not be so great. Most German authorities on filtration hold that preliminary sedimentation for twenty-four hours or even less is sufficient, most of the solid matters being precipitated within that time, if at all, and the filters being relied upon to remove the remainder, especially the finer particles and the bacteria. The English practice is to store the water for a longer time, though local causes related to the source of supply are the reason for this. Thus the Lea and Thames, from which the London companies take much of their water, are subject to extra pollution in times of flood, which are usually of short duration, and a sufficient reserve for such periods is of obvious value.

All storage reservoirs should, of course, be kept free from extraneous contamination, and should be cleaned from time to time. This necessitates an arrangement in pairs or groups, or a partitioning of large reservoirs, so that one part may be cleansed without putting the rest out of service. Weeds should be destroyed, as they sometimes give an unpleasant taste to the water. The water may also have a bad taste or odor from algæ and other species of minute plants, which especially favor a pure water exposed to sunshine. They are not known to be harmful, but it may be necessary to cover the reservoirs to get rid of them and their unpleasant properties.

Where a water is very hard or contains an excess of mineral matter it is frequently of advantage to treat it chemically. If the hardness is due to calcium bicarbonate in excess, it may be removed by the addition of a solution of calcium hydroxide to the water, *insoluble* calcium carbonate being formed and precipitated. The change is represented by the equation :

$$\mathrm{CaOCO_2CO_2 + Ca(HO)_2 = 2CaCO_3 + H_2O.}$$

Clark's process, based on this reaction, is as follows: About fourteen or fifteen hundred-weight of lime is allowed to each million gallons of water, the actual quantity of lime depending on the amount of bicarbonate in the water. The lime is slaked in a tank into which the water to be treated flows ; the mixture is well stirred and then allowed to stand for twelve hours, when the supernatant water is drawn off, the tank cleaned, and the process repeated. The water is not only softened in this way, but the precipitate also usually carries down with it much of the solid impurities and organic matters in the water. This process is extensively used in England, where much of the available water is derived from the underlying chalk-beds, and thus has a superabundance of the bicarbonate; but the writer is unaware that it finds any general application in this country, though it might be an advisable method of treatment in certain of our limestone districts.

If alum (aluminum sulphate) be added to an impure water, a decomposition of the salt occurs, the acid portion combining with the bases in the water and forming a flocculent precipitate of insoluble basic sulphates and aluminum hydroxide, which entangles in it and carries down the suspended impurities in the water, beside removing much of the dissolved organic and coloring matters. Moreover, careful experiments have shown that the addition of only about one grain of alum per gallon, followed by thorough agitation and subsequent settling for twenty-four hours, will almost invariably give a water free from germs and one that will tend to remain sterile for a considerable time; this possibly being due to removal of the food-supply of the bacteria.[1]

The use of alum is especially advantageous when a water contains a very fine silt or the like in suspension, and which is not removed by subsidence even after a considerable time. It is also to be used in conjunction with or preliminary to mechanical filtration, which latter, at the usual rate of operation, is oftentimes practically dependent upon alum for the furnishing of a clear safe water. Comparatively little alum is needed, even with a very dirty water—usually not more than one or two grains per gallon, and if the supply is practically adjusted to the condition of the water, as it should be, the extremely minute quantity of free alum that may sometimes pass through the filters is harmless and unimportant.

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[1] V. and A. Babes, Centralblatt für Bakteriologie und Parasitenkunde, 1892, vol. xii., No. 45.

Should the water be lacking in sufficient bases, which, however, is extremely improbable, it might contain when filtered a very little free acid, which can be readily neutralized by the addition of a correspondingly small quantity of sodium hydroxide or carbonate, the resulting salt affecting neither the healthfulness nor the palatability of the water. It has been suggested that the alum be first decomposed by the addition of sodium hydroxide, then washed free from the resulting sodium sulphate and the flocculent aluminum hydroxide added to the water, thus avoiding the chance of there being either free alum or acid in the cleared water; but experiments show that the results are not so good as when alum alone is used.

Regarding the danger from the use of water purified by the addition of alum, Hazen says: "Although alum in large quantities is undoubtedly injurious to health, it is neither a violent nor a cumulative poison; and the proposition that one part of alumina in a million parts of water is injurious to health must be regarded as conjecture rather than as a matter of proof or even of probability."

The Anderson process, which consists in agitation of the water with metallic iron before filtration, has been employed at Antwerp and elsewhere; but it is not clear that with large quantities of water better results are obtained than by simple filtration. The idea is that some of the iron is converted into soluble ferrous carbonate, which then oxidizes to insoluble ferric hydroxide and carries down with it the suspended and many dissolved impurities, and thus facilitates their removal by sedimentation and filtration. The difficulty in using this process on a large scale seems to be that the carbonate is not formed quickly enough, and also that too much of the iron may remain in solution even after filtration.

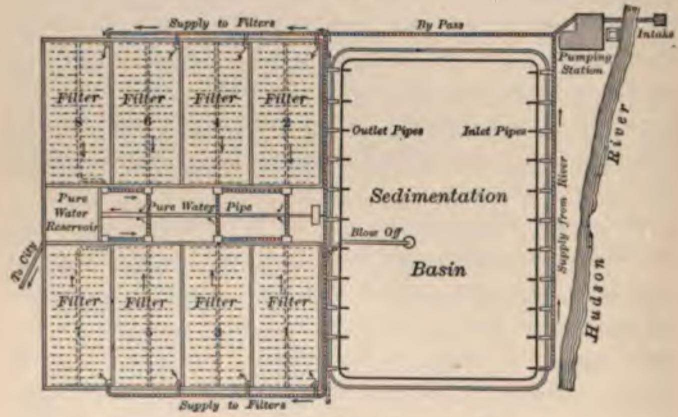
**Filtration.**—For the purification of large quantities of water, such as are needed for great cities, there can be no question that sand filtration is, in the majority of cases, the most available, satisfactory, and efficient method, though it may often be advantageously preceded by sedimentation or by chemical treatment, as already described. The former especially, by removing much of the suspended matter, will prolong the use of the filters between cleanings and thus materially lessen the cost of maintenance; while the latter may greatly improve the chemical quality of the filtered water.

Municipal filters of the type to be described are as yet not widely nor sufficiently well known in this country, but they have been used abroad with increasingly good results for upward of half a century, and they now furnish the daily supply of water to more than twenty millions of people. However, we may take credit in the knowledge that the most thorough and scientific investigation of their action and efficiency has been made on this side of the Atlantic, under the auspices of the Massachusetts State Board of Health, and that it is to this body that we are indebted for much of the positive information that we now have concerning them.

The limitations of this work do not permit a full discussion of the principles or merits of such filters, but the following details are given that the reader may appreciate the simplicity of their construction and the efficiency of their work. Those desiring more extended information are referred to the Massachusetts reports that discuss this subject, and to the excellent work of Hazen, already mentioned,[1] from which many of the accompanying statements and illustrations have been taken.

Almost without exception these filters now consist of a layer of clean sand of a certain degree of fineness spread upon a layer of gravel in a carefully prepared basin, the whole being under-drained and proper arrangements made for the controlling of the depth of water upon the surface, rate of flow of the filtrate, cleaning of filters, etc. (Fig. 33.) Such filters act primarily as strainers to remove the solid impurities from the water, but their efficiency is much increased by the sediment that is retained upon the surface of the sand and that forms a filter or "blanket" much finer than the latter and is capable of mechanically preventing the passage of most of the

FIG. 33.



Plan of filter-beds at Albany, N. Y.

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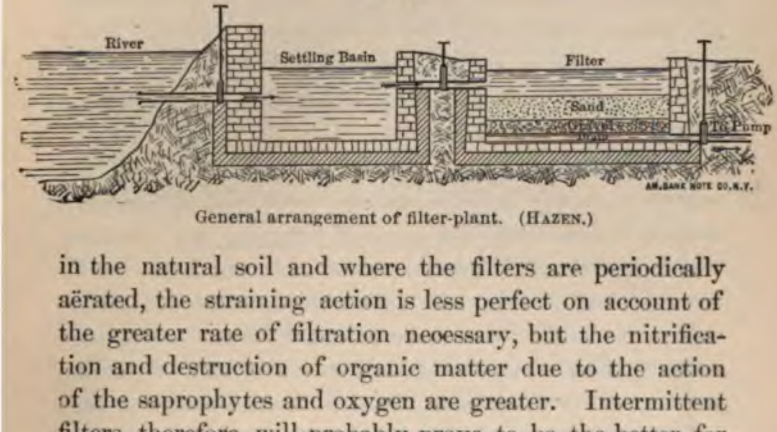
[1] Filtration of Public Water-supplies.

bacteria always present in a surface-water. Moreover, this removal of the bacteria is often largely due to the organisms themselves in the sediment-layer, because by forming a felt-like growth therein they not only increase the fineness of the strainer, but by acting as saprophytes they also decompose much of the organic matter and even kill the pathogenic bacteria. However, it now seems probable that for continuous filters the action is sometimes mainly mechanical, consisting in the removal of suspended matters and bacteria, and but slightly affecting the dissolved organic matters. On the other hand, in intermittent filtration, where the conditions more nearly resemble those in the natural soil and where the filters are periodically aërated, the straining action is less perfect on account of the greater rate of filtration necessary, but the nitrification and destruction of organic matter due to the action of the saprophytes and oxygen are greater. Intermittent filters, therefore, will probably prove to be the better for the purification of sewage or a very impure water, though usually their efficiency in removing bacteria seems to be inferior to that of continuous filters.

Fig. 34.



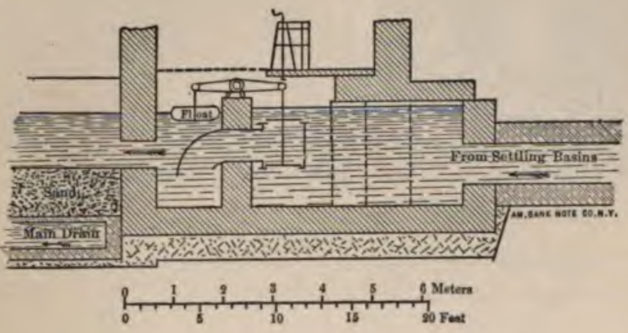
General arrangement of filter-plant. (Hazen.)

Where a water contains a very fine sediment or silt in large quantities, the sand bed may be clogged and choked in a few hours and before there is time for the formation of the bacterial film mentioned above, and the filtration must be more mechanical. For example, at New Orleans, where the Mississippi River contains an enormous amount of a silt so fine that much of it is submicroscopic and many of the particles even smaller than bacteria, the water is pumped from the river to a sedimentation basin capable of holding twenty-four hours' supply, through which it passes slowly, leaving the coarser and heavier sediment; then to a mixing basin, where alum is added as a coagulant to an extent not exceeding six grains per gallon, and then to the sand filter-beds. The "blanket" is thus formed by the coagulum due to the alum which commingles with and holds the silt, preventing the latter from entering and choking the filter. The filter-beds are cleaned daily or oftener by forcing from below first a liberal washing of filtered water and then a supply of air. The cost of this treatment is about $600 per day for a supply of 40,000,000 gallons.

The location of the filter-beds with respect to the source of supply and the storage reservoirs will depend largely on local conditions, cost of pumping, etc. Settling basins are almost essential where the water to be filtered is very turbid, even if only at intervals. Reference has already been made to the difference of opinion between English and Continental authorities regarding the size of these settling basins. As the filtration does not remove hardness due to dissolved minerals, it may also be advisable to use the Clark process previous to sedimentation and filtration. Part of the color due to peat or vegetable matters is removed by ordinary filtration, and still more may sometimes be destroyed by the previous addition of alum, but such preliminary treatment is unusual. Where the water comes from a lake or from a river with a slow current, settling basins are, of course, unnecessary.

Inasmuch as it is needful to govern the depth of the water upon the filter-beds according to the rate of flow desired, the thickness and resistance of sand, etc., and to prevent disturbance of the sand and sediment layer by the force of the entering current, some method of regulating the inflow is required. The accompanying illustration shows a comparatively simple arrangement for this purpose. (Fig. 35.)

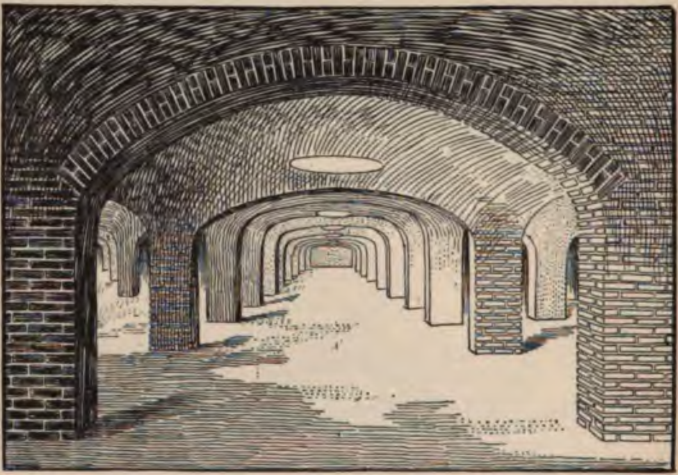
FIG. 35.



Regulation of inflow used at Hamburg. (HAZEN.)

The total area of the filter-beds will depend upon the amount of water supplied, the rate of filtration, and the proportion of area out of use while being cleaned. The total area is to be divided into beds, varying in number according to circumstances, so that one or more of these beds may be cleaned while the rest are in use. Large beds decrease the cost per acre on account of less masonry, etc., being needed, but it may be more difficult to maintain an even action over large areas. Evenness of action is, however, largely governed by the size and arrangement of the under-drains.

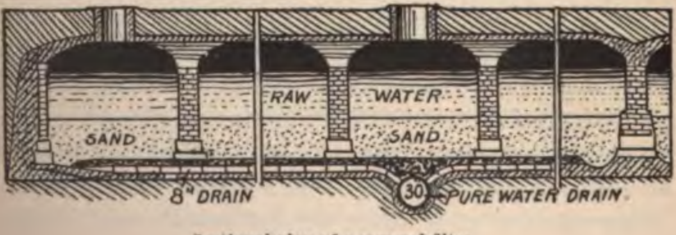
FIG. 36.



Interior of a covered filter ready for use.

The walls and bottoms of filter-beds should be made water-tight, that there may be no waste of the filtered water on the one hand, nor any ingress of foul soil-water on the other. The form of the filter-bed is immaterial,

FIG. 37.



Sectional plan of a covered filter.

provided evenness of work over the whole area is not impaired. Where the mean January temperature is below the freezing-point the beds should be covered, as the formation of ice upon them seriously impairs their efficiency, and as, moreover, a number of epidemics of typhoid fever and certain intestinal diseases seem to be directly traceable to ice-formation. This may have been on account of the overtaxing of the filters through increased difficulty in working, or because the sediment layer and the sand were disturbed in the removal of the ice.

As already stated, the materials used practically everywhere are clean sand and gravel, and the sharper the sand-grains the better. At the Lawrence Experiment Station of the Massachusetts State Board of Health "the size of a sand-grain is uniformly taken as the diameter of a sphere of equal volume, regardless of its shape." Moreover, as it is "the finest portion which mainly determines the character of sand for filtration," the *effective size* is taken to be "the size of a grain such that 10 per cent. by weight of the particles are smaller and 90 per cent. are larger than itself." As uniformity of grain is also important, the *uniformity coefficient* is "the ratio of the size of grain which has 60 per cent. of the sample finer than itself to the size which has 10 per cent. finer than itself." Obviously, the velocity of water through a layer of sand will depend upon the effective size of the grain, the thickness of the layer through which the water passes, and the loss of head due to the frictional resistance of the sand. A rise in temperature causes a progressive increase in velocity.

The effective sizes of sand-grain in use in most of the foreign filters average from 0.31 to 0.40 mm. In general, it may be said that the finer the sand the better is the quality of the normal filtrate and the less the danger of an unsafe effluent in case the sediment layer on top of the sand is broken; but, on the other hand, cost of filtration increases with the smallness of sand-grain, since the filters must be cleaned oftener and fine sands are harder to wash, as well as because the velocity of flow is slower through fine sands. All things considered, the best results will probably be obtained with a sand having a uniformity coefficient of not more than 3—the lower the better—and an effective size of from 0.20 to 0.35 mm., the latter depending largely upon the character and clearness of the water to be filtered.

The thickness of the sand layer should be such that it may be scraped a number of times before becoming so thin as to require replacing. The German Imperial Board of Health requires a thickness of at least twelve inches after the last scraping; while the original thickness should be from twenty-four to forty-eight inches, the thicker the better, provided the cost of the filter be not made too great and the rate of filtration be not too much diminished. The sand should be of the same degree of fineness throughout.

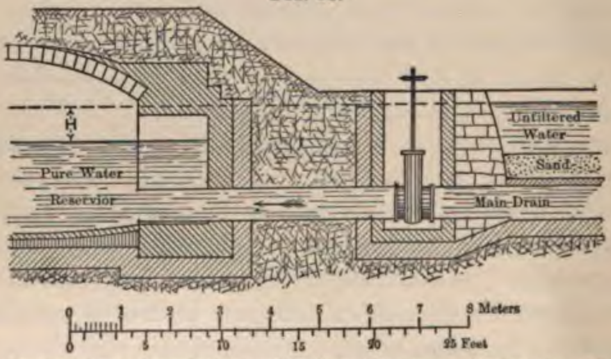
As for the gravel beneath the sand, there is no reason why it should be of excessive thickness. A depth of one foot is probably sufficient, provided the stones are of varying size, so arranged that the sand above will not work into and through the interstices, and that the water may freely enter the under-drains at low velocity. The loss of head in water flowing through a thin layer of gravel properly placed is comparatively slight. Foreign filters do have a gravel layer of two feet or more in thickness, as a rule, but careful experiments at Lawrence, Mass., show that this depth is unnecessary, provided that the gravel is properly laid as indicated, and that the under-drains are not too far apart.

The under-drains should be of such size and so constructed that the frictional resistance which they offer to the flow of the water is only a small percentage of that of the clean sand, and that the rate of filtration is the same over the whole area of the filter. There is usually a main drain along the middle of the filter-floor with smaller parallel lateral drains leading into it at regular intervals. The drains may be made of brick with open joints, or, for the laterals, of tile, which is usually cheaper. Care must always be had that the openings are sufficient in number and size to admit the water freely.

The area drained should vary from about 300 square feet for a 4-inch lateral drain to 4400 square feet for a 12-inch main, the velocity of flow in these being respectively 0.30 and 0.51 foot per second; while larger drains should have a cross-section of at least one-six-thousandth of the drained area. The European custom of ventilating drains by means of pipes passing up through the sand and water above is not to be commended, since such ventilation apparatus is unnecessary, increases the cost of the filters, and, what is worse, may allow impurities to contaminate the filtered water in the under-drains.

Recently it has been suggested that the filter-beds be constructed directly over the storage reservoirs for the filtered water, the beds being supported on suitable steel columns resting on concrete foundations in the bottom of the reservoirs. The bottom layer of the filter, composed of gravel or broken stone, would rest on steel tubes or bars several feet above the level of the water in the reservoir, thus allowing the filtrate to be aërated as it falls through the intervening space. Theoretically, it would seem that the plan is a good one, and actual results indicate that it practically is so. Some of the advantages are the absence of under-drains and loss of the resistance factor due to them, the aëration of the filtrate as indicated, and also the practically continuous aëration of the filter-bed itself, thus enabling the saprophytic bacteria in the upper layers to carry on their work of oxidizing and nitrifying the organic impurities of the water. One serious objection to such a filter is that an accidental overflow would contaminate at once all the filtered water in the storage reservoir.

FIG. 38.



Simplest form of regulating outflow from filter-beds. Stralau filters at Berlin. (HAZEN.)

Although it has been the custom to keep the depth of water upon the filter-beds in excess of the loss of head, this is not essential. On foreign filters the usual depth is from 36 to 52 inches, though less than this might suffice n many instances. The necessity of regulating the inflow nd outflow and of maintaining a constant level must not e overlooked if uniform results are desired.

Summarizing the preceding statements, the loss of head and rate of filtration will depend upon the depth of water on the filters, the thickness of the sand layer, size of sand-grains, resistance of under-drains, temperature, etc., and all these will likewise affect both the cost and the efficiency of the filtration.

Where the water is taken directly from a river, or if the opportunity for sedimentation has been brief, 2,000,000 gallons per acre per day will probably be a safe rate of filtration to maintain continuously, though with a clear water or in emergencies a rate one-half greater will very likely not materially alter the quality of the filtered water or increase the risk. But in general as the rate increases the efficiency decreases. However, very careful and thorough experiments preliminary to the construction of the Philadelphia filters have shown that in the case of some waters, at least, the rate may safely be increased to even 5,000,000 and sometimes to almost 6,000,000 gallons, provided the water be first passed through a so-called "rough filter" made of such materials as broken coke, lumps of burned clay, etc. Where the filters are constructed above the storage reservoirs in the manner described, it is claimed that much larger quantities of water may be filtered in a given time with equally good results. If this be so, it is probably due to the increased saprophytic and oxidizing action resulting from the continuous aëration of the filter.

As the sediment accumulates and deepens upon the surface of the sand the rate of flow necessarily diminishes, and it becomes necessary after a time to remove the deposit. This is done by carefully scraping off the top layer of the sand to the depth of from one-half to one and one-half inches, repeating the scraping as often as may be necessary until the thickness of sand-above the underlying gravel is near the permissible minimum. Then the sand which has been removed, and which has meanwhile been thoroughly washed by a stream of the filtered water, driven, if necessary, by a force-pump, is carefully replaced, packed, and levelled upon the beds. These do not again attain their greatest efficiency until a certain amount of sediment from the water has once more collected upon them, and it is, therefore, not advisable to use the filtered water for some time after the cleaning and until bacteriological tests show that the maximum purification is being attained.

An essential in the management of all large filters is the daily bacteriological and chemical examination of both the filtered and unfiltered water. This not only serves to give warning of any accident to the filter, but is necessary, as the best test of the efficiency of a sand filter is the percentage of bacteria which it takes from unfiltered water. Unless a filter is holding back from 98 to 99 per cent. or more of the bacteria, it needs close inspection, although it must be remembered that it is more difficult to get good results with a badly polluted water than with one that is comparatively pure.

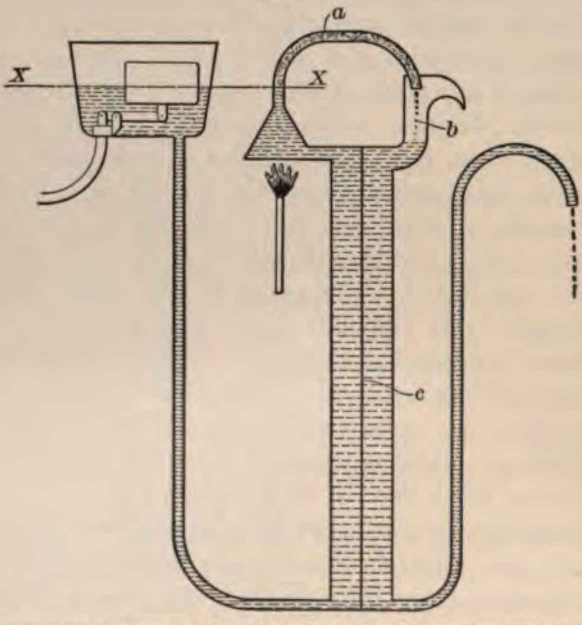
**Domestic Purification of Water.**—Boiling destroys living organisms and disease germs ; it also drives off the carbon dioxide and other gases of the water and causes the precipitation of many mineral substances held in solution by these gases. This is especially the case, as has been stated, where the water is hard from the presence of calcium bicarbonate in excess ; but iron is also often thrown down by boiling. If the water contains a very fine sediment, not removed by settling or filtration, it may be advantageous to add a little alum and chalk to produce the flocculent precipitate already described. Potassium permanganate has little effect in purifying a foul water. Agitation with iron-filings may do a little good by favoring oxidation of organic matters. Tannin is believed to destroy micro-organisms, and a harmful water may sometimes be made usable by boiling with tea-leaves or other astringents. Citric acid is said to destroy algæ. Aëration and agitation improve a water after distillation or boiling by restoring oxygen and also by oxidizing organic matters. Remember that boiled water is prone to take up gases of any kind, whether impure and offensive or otherwise. Organic matters are got rid of by boiling, exposure to air, agitation, addition of alum, astringents, charcoal, etc.; calcium bicarbonate, by boiling or by adding caustic or slaked lime or a little sodium hydroxide; iron, by boiling and by adding lime-water. According to Parkes and Rideal, fifteen grains of acid sodium sulphate to the pint (1 in 500) will destroy typhoid bacilli in five minutes. Calcium and magnesium sulphates and chlorides cannot readily be removed. Some plants help to purify by means of the oxygen which they give to the water.

Distillation gives, of course, a water free from harmful impurities, but it has lost its gases, and may be improved in palatability by aëration or by being charged with carbon dioxide gas. Stills for domestic use, capable of supplying an abundance of water for drinking and cooking purposes, can now be purchased at moderate cost. The main objection to distillation in the household is that the process is somewhat slow and tedious.

Comparatively recently an apparatus has been invented and introduced which furnishes a boiled water free from disease germs, yet unchanged in taste by the boiling, and at nearly the same temperature as the water entering the apparatus. This is the Forbes (formerly the Waterhouse-

Forbes) sterilizer. The principles involved in its construction and operation are that only a small bulk of water is being boiled at any instant; that it is boiled for only a very short time, thus preventing loss of the original gases and taste; that all disease germs are killed by the boiling; that it is impossible for water which has not been boiled to pass through the apparatus; and that the heat of the boiled water is used to warm the unboiled water (thus economizing fuel) at the same time that the latter is made to cool the former.

FIG. 39.



Diagrammatic representation of the principle of the Forbes sterilizer.

Reference to the diagram (Fig. 39) shows that the water can rise no higher than the level $X$ until it "*boils over*" through the spout $a$ into the receiver $b$. The interchange of heat takes place through the diaphragm $c$, which in the apparatus itself is very thin and corrugated, so as to expose a large surface to the water on the two sides of it.

This apparatus is furnished in a suitable size for household use. It is also made on a large scale and in a convenient form for transportation, having been adopted by the United States Army as being "well adapted for the abundant supply of sterile water to troops in the field." The Board of Medical Officers appointed by the Surgeon-General of the Army to consider the filters and other apparatus of the kind submitted made the following report:

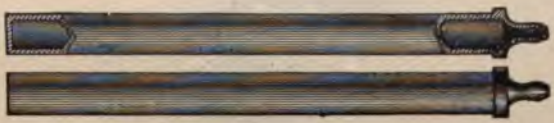
"The advantages of this most ingenious water sterilizer are: First. That water passing through it, although brought to the boiling-point, is maintained at this temperature for so short a time as not to be deprived of its natural gases, and hence not rendered unacceptable to the taste. Second. That all living micro-organisms . . . are destroyed by the degree of heat attained during the passage of the water through the apparatus. Third. It furnishes an abundant supply of practically sterile water, and may be kept in action, if necessary, for the entire twenty-four hours without renewing the supply of oil in the reservoir, and at a cost of about one-fourth of a cent an hour. Fourth. The water, having been slowly heated until it reaches temporarily the boiling-point, is afterward cooled to within 4 or 5 degrees F. of the water entering the apparatus. This is one of the important advantages possessed by this sterilizer. By placing the bottom of the exchange in a freezing mixture the temperature of the sterilized water as it flows from the machine may be reduced below 40° F. Fifth. Its durability and freedom from liability to breakage. Sixth. The facility with which the apparatus may be put together and entirely taken apart; only one tool, a wrench, being required for this purpose. Seventh. The facility with which the apparatus can be thoroughly cleansed. This is effected by the removal of the rubber cocks, thus permitting a complete flushing out of both exchanges. The fact that the apparatus does not clarify the water is also deemed of no particular importance by the Board, since this may be easily effected prior to its passage through the sterilizer by means of one or two water barrels partially filled with fine and coarse sand and placed at a proper height above the sterilizer. As a result of exhaustive experiments . . . the Board is of the opinion that this sterilizer is superior to all filters or other water sterilizers submitted for trial. We, therefore, after a careful consideration of the requirements, respectfully recommend that the Forbes sterilizer be issued for the use of troops serving in the field."

House filters are dangerous unless properly cared for, and may give more and worse impurities to the water than they take from it. What a filter takes from a water is left in the filter unless otherwise removed, and an accumulation of such impurities cannot improve the water passing through them. The organic matters will undergo decomposition and putrefaction, and will furnish a good culture-medium for bacteria, and these, together with the putrefaction-products, will in most cases be carried through the filter with and by the filtered water. A filter has no miraculous power to annihilate filth, and the size of a filter must always limit the work it can do, whatever the materials used.

According to Parkes, the requisites of a good filter are:

That every part shall be easily accessible for cleansing or renewing the medium. 2. That the filtering medium shall have sufficient purifying power and be present in sufficient quantity. 3. That the medium give nothing to the water favoring the growth of low forms of life. 4. That the purifying power be reasonably lasting. 5. That there be nothing in the construction of the filter itself capable of undergoing putrefaction or of yielding metallic or other impurities to the water. 6. That the filtering material shall not clog, and that the flow of water be reasonably rapid; to which may be added: 7. That the filtering medium be such that it can be readily cleansed and sterilized, or else so cheap that the removal and replenishing may not be neglected when necessary on account of the expense.

FIG. 40.



Tubes of unglazed porcelain for Pasteur filter.

House filters may be divided into three classes: (*a*) those entirely disconnected from the water-supply pipes of the house; (*b*) those connected with the water-pipes, but intended to filter only a limited quantity, as for drinking, cooking, etc.; (*c*) those connected with the house service-pipe and intended to filter all the water used in the house. The same filtering media may be used in all three classes, but it will be found best in the two first to employ substances through which the water passes slowly, while the latter class must necessarily filter the water more rapidly in order to yield a sufficient supply. It will often be the quality of the normal filtrate and the less the danger of an unsafe effluent in case the sediment layer on top of the sand is broken; but, on the other hand, cost of filtration increases with the smallness of sand-grain, since the filters must be cleaned oftener and fine sands are harder to wash, as well as because the velocity of flow is slower through fine sands. All things considered, the best results will probably be obtained with a sand having a uniformity coefficient of not more than 3—the lower the better—and an effective size of from 0.20 to 0.35 mm., the latter depending largely upon the character and clearness of the water to be filtered.

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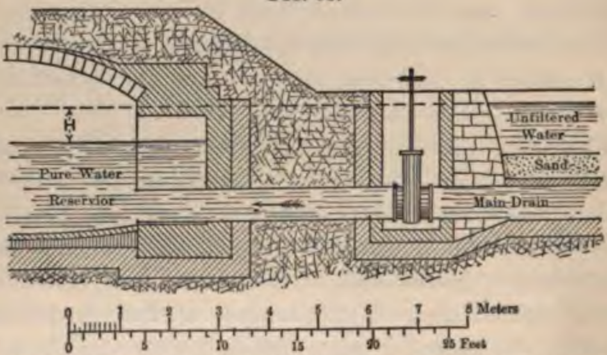

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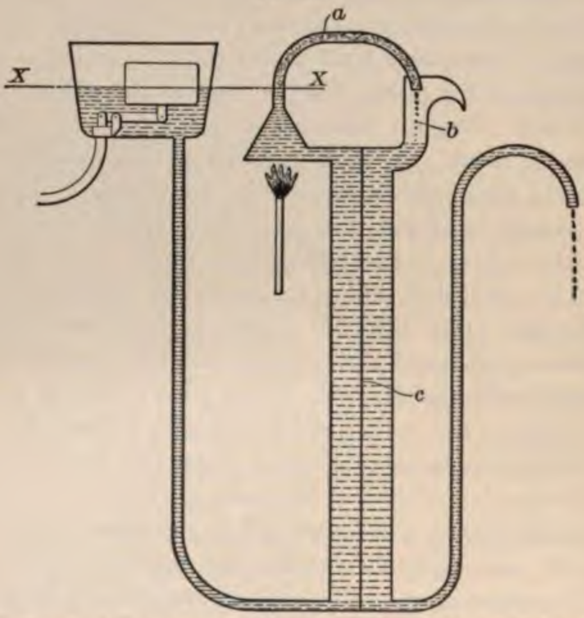


Diagrammatic representation of the principle of the Forbes sterilizer.

Reference to the diagram (Fig. 39) shows that the water can rise no higher than the level *X* until it "*boils over*" through the spout *a* into the receiver *b*. The interchange of heat takes place through the diaphragm c, which in the apparatus itself is very thin and corrugated, so as to expose a large surface to the water on the two sides of it.

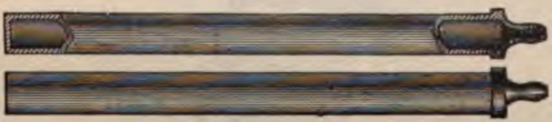
This apparatus is furnished in a suitable size for household use. It is also made on a large scale and in a convenient form for transportation, having been adopted by the United States Army as being "well adapted for the abundant supply of sterile water to troops in the field." The Board of Medical Officers appointed by the Surgeon-General of the Army to consider the filters and other apparatus of the kind submitted made the following report:

"The advantages of this most ingenious water sterilizer are: First. That water passing through it, although brought to the boiling-point, is maintained at this temperature for so short a time as not to be deprived of its natural gases, and hence not rendered unacceptable to the taste. Second. That all living micro-organisms . . . are destroyed by the degree of heat attained during the passage of the water through the apparatus. Third. It furnishes an abundant supply of practically sterile water, and may be kept in action, if necessary, for the entire twenty-four hours without renewing the supply of oil in the reservoir, and at a cost of about one-fourth of a cent an hour. Fourth. The water, having been slowly heated until it reaches temporarily the boiling-point, is afterward cooled to within 4 or 5 degrees F. of the water entering the apparatus. This is one of the important advantages possessed by this sterilizer. By placing the bottom of the exchange in a freezing mixture the temperature of the sterilized water as it flows from the machine may be reduced below 40° F. Fifth. Its durability and freedom from liability to breakage. Sixth. The facility with which the apparatus may be put together and entirely taken apart; only one tool, a wrench, being required for this purpose. Seventh. The facility with which the apparatus can be thoroughly cleansed. This is effected by the removal of the rubber cocks, thus permitting a complete flushing out of both exchanges. The fact that the apparatus does not clarify the water is also deemed of no particular importance by the Board, since this may be easily effected prior to its passage through the sterilizer by means of one or two water barrels partially filled with fine and coarse sand and placed at a proper height above the sterilizer. As a result of exhaustive experiments . . . the Board is of the opinion that this sterilizer is superior to all filters or other water sterilizers submitted for trial. We, therefore, after a careful consideration of the requirements, respectfully recommend that the Forbes sterilizer be issued for the use of troops serving in the field."

House filters are dangerous unless properly cared for, and may give more and worse impurities to the water than they take from it. What a filter takes from a water is left in the filter unless otherwise removed, and an accumulation of such impurities cannot improve the water passing through them. The organic matters will undergo decomposition and putrefaction, and will furnish a good culture-medium for bacteria, and these, together with the putrefaction-products, will in most cases be carried through the filter with and by the filtered water. A filter has no miraculous power to annihilate filth, and the size of a filter must always limit the work it can do, whatever the materials used.

According to Parkes, the requisites of a good filter are: 1. That every part shall be easily accessible for cleansing or renewing the medium. 2. That the filtering medium shall have sufficient purifying power and be present in sufficient quantity. 3. That the medium give nothing to the water favoring the growth of low forms of life. 4. That the purifying power be reasonably lasting. 5. That there be nothing in the construction of the filter itself capable of undergoing putrefaction or of yielding metallic or other impurities to the water. 6. That the filtering material shall not clog, and that the flow of water be reasonably rapid; to which may be added: 7. That the filtering medium be such that it can be readily cleansed and sterilized, or else so cheap that the removal and replenishing may not be neglected when necessary on account of the expense.

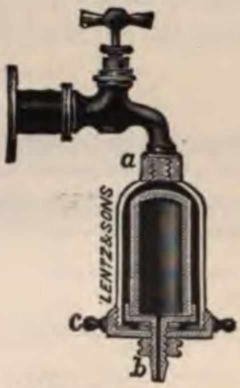
Fig. 40.



Tubes of unglazed porcelain for Pasteur filter.

House filters may be divided into three classes: (*a*) those entirely disconnected from the water-supply pipes of the house; (*b*) those connected with the water-pipes, but intended to filter only a limited quantity, as for drinking, cooking, etc.; (*c*) those connected with the house service-pipe and intended to filter all the water used in the house. The same filtering media may be used in all three classes, but it will be found best in the two first to employ substances through which the water passes slowly, while the latter class must necessarily filter the water more rapidly in order to yield a sufficient supply. It will often be advantageous to have a settling tank connected with those of the first class, to prolong the safe use of the filter as long as possible; while the same object is gained in some of the second class by bringing the water in at the bottom, in which case there should be a space below the filtering medium to allow the suspended matters to fall away from the latter. Those intended to filter the whole supply of the house are generally cleansed by reversing the current and washing the collected dirt out of the filter into a drain or sewer, the first water passing through the filter after this is done being also discarded. In such filters the quantity of filtering material should be sufficient to purify thoroughly the water passing through it, and yet should not be so heavy that the reverse or washing current cannot lift it and separate the particles so that by their scouring action upon one another they may be cleansed and all the dirt washed out. These filters, also, may be so arranged that a small quantity of a coagulant, like alum, is

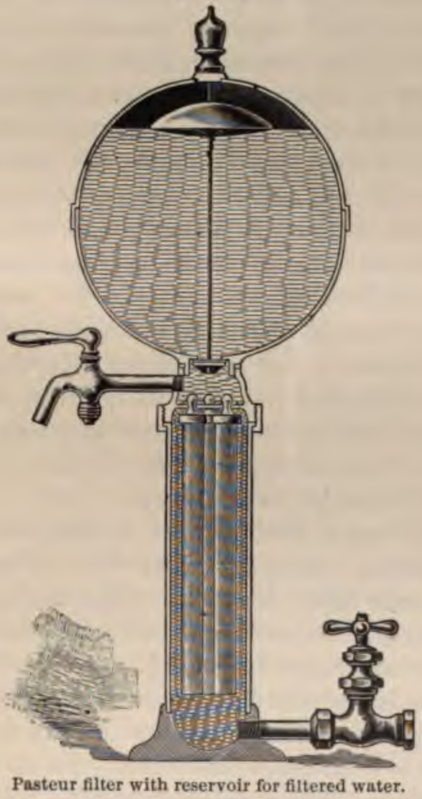
FIG. 41.



Berkfeldt filter attached to tap.

automatically added to the water before filtration. If this be done, care must be had to supply no more of the coagulant than suitable tests show to be necessary, else the excess may be carried through the filter in solution.

FIG. 42.



Pasteur filter with reservoir for filtered water.

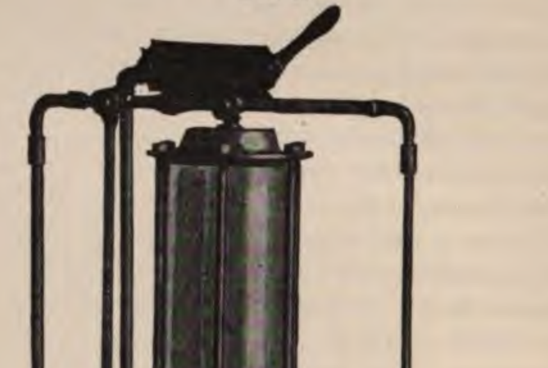
Several filters of the second class have been provided with self-cleansing devices to obviate opening or taking the filter apart as frequently as would otherwise be necessary. Of these one of the very best is that of the Columbia filter, which has a porous tube (or tubes) very similar to those of the Pasteur-Chamberland type. Around this tube is a mass of white quartz sand, which is set in active motion by the opening of the cleansing valve and thoroughly scours the exterior of the filtering tube until the latter is entirely cleansed of the suspended matter which it has removed from the water. Moreover, as the water is received into an air-tight reservoir and accumulates there, when not immediately used, until the air-pressure in the reservoir equals the pressure in the street-main, the opening of the cleansing valve permits the compressed air to drive the filtered water back through the filtering tube and thus to cleanse its pores of any impurities that may have entered them. A few moments each day and the turning of a valve suffice for the cleansing, and so effectual is it that most of the objections to tube-filters are eliminated. In fact, while giving a germ-free water, more is obtainable per day per tube with this filter, and there is less annoyance, loss of time, and risk of breakage of tubes in the cleansing.

No matter what kind of filter is used, the drinking-water should always be boiled in times of epidemics or when the water before filtration is especially impure; for, though the Berkfeldt, the Pasteur-Chamberland, and a few other filters are practically bacteria-proof, there always remains a possibility that disease germs may by some means pass through the filtering medium or gain access to the water after it is filtered. The writer's own opinion is that there is a saprophytic or biologic action in most good filters that are regularly and frequently cleaned very similar to that which takes place in filter-beds on a large scale, and that ordinarily few, if any, bacteria pass through with the water; but, nevertheless, the risk should not be taken if there is danger of incurring disease at any time.

Filters in which the material is cemented up so that it cannot be removed for cleaning or renewal should not be used. Sponge, wool, etc., are liable to decompose and give organic matter to the water and, moreover, cannot be thoroughly cleaned. Asbestos acts only as a mechanical filter and may allow albuminous matter and disease germs to pass. Asbestos-cloth may be used, however, to support the other filtering media in those filters where the water-supply enters at the bottom, and it has the advantage that it can be perfectly sterilized by fire. Small tap filters are insufficient for the work required of them and soon clog. Pocket filters are simply strainers, and have little oxidizing power. They may be quite useful for tourists, hunters, etc., but should be frequently sterilized by boiling. Ordinarily, filters should not be placed in rain-water cisterns, but outside, where they may be readily cleaned.

Among the best filtering media are sand, animal charcoal, magnetic carbide of iron, spongy iron, etc. Unglazed porcelain or bisque, as is used in the Pasteur-Chamberland filter, is an excellent medium, and is practically germ-proof, though some observers state that bacteria will pass through uncleaned filters of this material after five or six days. Others claim that these are not bacteria, but only the mycelia of certain budding fungi, with no power of reproduction, and the former statement seems to have been positively disproved with respect to the germs of typhoid fever, colon bacilli, and similar organisms. The tubes of the Berkfeldt filter were formerly made of diatomaceous earth, moulded into shape by powerful hydraulic pressure, so that the water percolated through the pores of the minute fossil shells rather than between them. If kept clean, these give good service, but it has been recently stated that typhoid bacilli will pass through them after

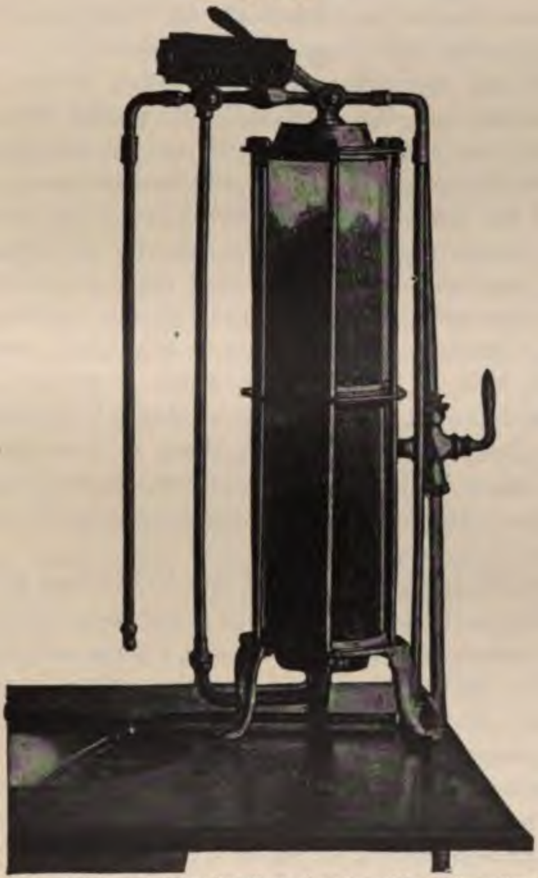
FIG. 43.



Glass model of Loomis-Manning filter, showing filter in action.

several days. Stone filters may be good, and resemble the porcelain ones in action, but are apt to be slow and must be cleansed often. Sharp, clean sand, not too fine, has fair filtering properties, as it arrests most of the suspended matters and bacteria, beside oxidizing somewhat the dissolved organic matters. It makes a good first layer

FIG. 44.



Glass model of Loomis-Manning filter, showing self-scouring of material during cleansing.

for a filter, because it is cheap and can be easily renewed or else readily cleansed and sterilized by boiling. Crushed quartz is of practically the same nature.

Animal charcoal is, when fresh, an excellent material, as it removes both suspended and dissolved matters, organic and inorganic, and even color. It acts both mechanically and chemically, and with a good volume of it, water may pass through rapidly and be well purified. But after a time it ceases to be effective, nor must water be left too long in contact with it, as it will give up organic matter to the water again and also calcium phosphate, the latter especially favoring the development of micro-organisms. Moreover, fresh organic matter, and possibly bacteria, are said to pass through it readily, though dead or decomposing matter is retained and rapidly destroyed. It should be changed or cleansed, even when in sufficient bulk, three or four times a year; oftener if the water to be filtered is very impure. It is more efficacious than any other substance in removing lead from water.

Magnetic carbide of iron is one of the best filtering materials, as it has considerable power in oxidizing organic matters, converting them into nitrates and nitrites, the action being greater the longer the water is in contact with it. It acts partly by surface condensation of oxygen; partly, perhaps, by electrolytic action. If sand be used as a first layer to remove solid matters so that the water reaches the carbide perfectly clear, and if the sand be frequently renewed or cleansed, the carbide need never be changed; but the filtration must be intermittent so that the carbide may be frequently aërated. Spongy iron has an action very similar to that of the magnetic carbide on organic matters, and, like it, the action is the greater the longer the contact. It must be kept covered with water to prevent rusting and caking, and should be renewed about once a year. The small amount of iron that the magnetic carbide and spongy iron give to the water may be removed by passing it through a layer of pyrolusite—a crude magnesium oxide. A mixture of pyrolusite and sand or crushed quartz makes an excellent filtering material.

Ice should not be added to filtered or drinking-water, as freezing, even for a long time, may not kill certain disease germs. Prudden has kept typhoid bacilli frozen in ice for more than three months without destroying their power of growth and reproduction when brought to a suitable temperature. The same objections do not, of course, pertain to artificial ice carefully made from distilled water as to that from polluted ponds or rivers; but it is well to cool the water by placing it in stoppered bottles upon ice or in vessels surrounded by ice rather than by adding the ice to the water directly.

The inadvisability of using ice-water freely as a beverage should be mentioned here, as the habit is almost certain to cause much harm to the digestive apparatus, and to give origin not only to intractable dyspepsias, but to troubles even more serious. If used at all, ice-water should be taken slowly and in small quantities, and as little as possible should be imbibed at meal-time, in order to prevent chilling of the stomach and consequent checking of the digestion. Its use and the liking for it are mainly a matter of habit which it is hygienic wisdom to overcome.

**The Examination of a Drinking-water** should have regard to its physical, bacterial, and chemical properties as well as to a consideration of all the conditions affecting its source, storage, and distribution. Consequently, a decision on the purity of water should be governed by all the available knowledge of the circumstances: whether it is well-water, spring-water, rain-water, or river-water; whether it has been at any time exposed to pollution; in what kind of a cistern or reservoir it has been stored, etc.

A physical examination of water considers the color, clearness, sediment, lustre, taste, and smell. Pure water has a bluish tint, but most waters are grayish, greenish, yellow, or brown. Yellow or brown waters are subject to suspicion, as the color may be due to animal matter or sewage, though vegetable matters or iron may give the same color. Green waters are usually harmless, the color being due to vegetable matters. The color is judged by allowing the sediment to settle and then siphoning or pouring off the supernatant water into a tall glass vessel or tube to the depth of about twenty-four inches; the color is then compared with that of a similar depth of distilled water, looking down through both upon a white surface.

The clearness of a water is to be estimated in the same way, except that the sediment is to be shaken up with the water. The depth needed to obscure print of a certain size and kind of type may be used as an index. Where the solid matter will not readily settle, owing to the minuteness and lightness of the particles, one should determine whether the use of a coagulant and filtration is indicated, or whether boiling will tend to precipitate the ediment. The sediment may be roughly judged by the ye as to whether it is mineral or otherwise; it should also e examined microscopically, for which purpose it may be ollected by using a centrifugal apparatus or by allowing t to settle from the water in a conical glass and then removing it to the slide with a pipette. Mineral matters are recognized by their crystalline or amorphous structure or by micro-chemical tests; vegetable cells, portions of leaves, etc., by their structure and the presence of chlorophyll; animal substances, as hair, wool, epithelial and other cells, by their peculiar characteristics. Dark-brown, globular masses may come from sewage. Anything indicating that water has come from human habitation renders it suspicious, as it may therefore contain sewage or other polluting substances. Some of the larger animalculæ and sometimes iron may be detected with the naked eye.[1]

The lustre is supposed to indicate the amount of aëration; it may be nil, dull, vitreous, or adamantine. It should not be forgotten that a very impure water may be clear, bright, and sparkling.

Any water of peculiar or unpleasant taste should be considered with suspicion. Dissolved animal matters may be tasteless, but suspended substances give a peculiar taste, whether animal or vegetal. Iron is about the only ordinary mineral that can be tasted in small quantities. Good water depends for its taste mainly upon its gases, and water free from gas tastes flat.

The smell of a water, if it has any, may be brought out by heating gently to about 110° F., or by boiling it. This may make evident a fecal odor, although hydrogen sulphide may mask this latter; in such a case the sulphide may be removed by adding a little cupric sulphate to the water. The odor may also be developed by allowing the water to stand in a stoppered bottle in a warm place for a few days.

A bacteriological analysis is almost as necessary as a chemical one, for purity in the one respect does not necessarily indicate purity in the other. The presence of *Bacterium coli communis* in a water, irrespective of any pathogenic organisms, would create more than a suspicion of contamination by fecal matter, as this microbe is practically a constant occupant of the human intestinal tract.

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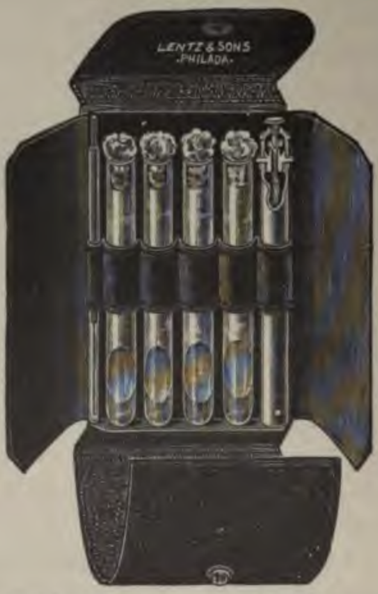
[1] See J. C. MacDonald's Guide to Microscopic Examination of Drinking-water.

FIG. 45.



Pocket-case containing sterilized culture-tubes, platinum needle, and alcohol lamp, used for obtaining cultures for diagnosis, etc.

But water may be capable of carrying typhoid or other infection and yet be free from colon bacilli, since the disease germs may have been introduced into the water from urine rather than feces.

Water may be collected for bacteriological analysis in sterilized, closed bulbs blown from glass tubing. The heat used in sealing the ends creates a partial vacuum within the bulb, so that if the tip of one end be broken off beneath the surface of the water, the latter is drawn into the bulb, which can then be resealed and conveyed to the laboratory. But as some of the bacteria may multiply rapidly in transportation and as some species may even destroy others, it is always best, if possible, to inoculate the tubes of sterilized culture-media at the place where the supply for examination is obtained. Or one may add a small quantity of the water to melted nutrient gelatin at the time when the samples are taken and make plate cultures in the manner already described. The number of colonies resulting therefrom will indicate practically the number of bacteria in the volume of water added to the gelatin.

The details of some simple but fairly accurate tests and methods employed in the chemical analysis of drinking-water will be given in another chapter. Here we need only consider the influence that the substances sought for in the analysis have in affecting potability, and within what limits we may consider them as being permissible in drinking-water. The water should be filtered or free from sediment for all the tests, except in the estimation of nitrogen as ammonia compounds and as organic matter, and of the oxygen-consuming power of the water.

The amount of total solids will vary with the source of the water, and much more may be present in some cases without risk of harm than would be safe in others; but usually the proportion should not exceed 50 or 60 parts in 100,000. Only a small portion should be volatile, and there should be little charring on ignition, except in the case of waters from peaty soils; nor should there be any odor on ignition, especially of ammonia compounds, as that would indicate an excess of animal organic matter. Deep well-water will probably have much more total solids than rain-water or clear river-water, the excess being mainly mineral substances dissolved from the strata through which the water passes.

Even the purest waters contain a little chlorine, usually in the form of sodium chloride; but, as the latter is a constant constituent of household slops and sewage in general, any excess of chlorine above the amount common to the water of the district, unless otherwise accounted for, will be decidedly suspicious, and sewage contamination should be looked for. So, also, any sudden increase in the proportion of chlorine would very likely indicate the accession of some new source of contamination to the water. Unless accounted for by the strata traversed or by the locality, more than 3 parts of chlorine in 100,000 of water is very suspicious.

The presence of considerable "free ammonia" in rain-water is not a bad sign, as it has probably been absorbed from the air; but the same amount in subsoil-water, especially if with an excess of chlorine, would indicate probable contamination with urine, as the latter rapidly undergoes ammoniacal putrefaction. In such a case there will probably also be considerable "albuminoid ammonia," but much albuminoid ammonia with little free ammonia and chlorine generally indicates vegetable contamination. The writer is acquainted with a case in which, although the water is pure and from an unpolluted source, the albuminoid ammonia and chlorine are in marked excess, the former being altogether of vegetable origin—from a peaty soil—and the latter characteristic of the whole district, which is near the sea-coast. The free ammonia is, however, slight in amount. An excess of free ammonia, chlorine, nitrates, and nitrites indicates animal contamination, though, if the pollution be by effluvia alone, there may be no excess of chlorine.[1] The total ammonia in a usable water should not be over 0.13 or 0.15 part per 1,000,000. If there is almost no "free" ammonia, the "albuminoid" may amount to 0.10 part per 1,000,000 without giving cause for suspicion; likewise, if there is but little "albuminoid," there may be considerable "free" ammonia; but if the "albuminoid" exceeds 0.05 part per 1,000,000, the "free" must not be greater than this proportion. The simplest test for ammonia is by means of Nessler's reagent—a solution of a double iodide of potassium and mercury. It gives a yellow or yellowish-brown coloration when ammonia is present.

Organic matters of animal origin, and therefore nitrogenous, are during oxidation partially converted into ammonium compounds, and these, by the action of certain bacteria, may be further oxidized into nitrites and nitrates. "Nitrification takes place under the influence of microbes, the habitat of which does not extend more than a few yards below the surface of the soil. The nitrifying action is probably exerted only upon the ammonium which is formed from the organic matter. The presence of some substance capable of neutralizing acids is necessary to continuous action. Calcium and magnesium carbonates fulfil this function. Nitrates are the final result of this action; nitrites are present at any given time only in small quantity."[2] Deep water may, of course, also contain nitrates taken up from strata rich in these salts.

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[1] Kenwood's Hygienic Laboratory, p. 49.

[2] Leffmann and Bevan, Examination of Water, 2d edition, p. 13.

Although nitrites and nitrates are not harmful in the quantities usually found in water, and though the water containing them may have been thoroughly purified by natural filtration through the soil, their presence, as will be seen from the above remarks, is important in determining the character of the water. The presence of the slightest trace of nitrites is always suspicious, and any marked amount of nitrates, excepting possibly in a deep water, should require close investigation; the nitrates and nitrites together measured in terms of nitrogen should not exceed 1 part per 1,000,000.

The hardness should not be greater than that indicated by 20 or 30 parts of chalk in 100,000, and the more "temporary" in proportion to the "permanent" hardness the better.

Phosphates, not from phosphatic strata, help to indicate sewage contamination. So, also, do sulphates, though these by themselves may come from unimportant sources.

It will be seen from the above statements that the opinion regarding any water must be based on a broad consideration of all the circumstances in relation to it, and not from the presence or absence in it of any one or two substances which are not in themselves harmful. The presence of poisonous metals above the limits of safety, however, would alone contraindicate the use of a water. For instance, there should not be more than 0.04 grain of lead or copper, 0.25 grain of zinc, or 0.5 grain of iron to the gallon in any water, and the faintest trace of arsenic condemns it.

The following table has been adapted from Parkes:

### CLASSIFICATION AND PROPERTIES OF VARIOUS WATERS.

| Class. | Physical. | Microscopical. | Chemical (parts per 100,000). |
|---|---|---|---|
| I. Pure water. | Colorless or bluish tint; transparent, sparkling, and well aërated; no sediment visible; no smell; taste palatable. | Mineral matter; vegetable endochrome; large animal forms; no organic *débris.* | Chlorine under 1.4<br>Total solids under 7.14<br>Ammonia under 0.007<br>Nitrogen, as nitrites & nitrates, under 0.023<br>Total hardness 8.5 |
| II. Usable water. | Colorless or slight greenish tint; transparent, sparkling, and well aërated; no suspended matter, or easily separated by coarse filtration or subsidence; no smell; taste palatable. | Same as for pure water. | Chlorine under 4.3<br>Total solids " 42.8<br>Ammonia " 0.015<br>Nitrogen, as nitrites & nitrates under 0.125<br>Total hardness 17.3 |
| III. Suspicious water. | Yellow or strong green color; turbid; considerable suspended matter; no smell, but any marked taste. | Vegetable and animal forms, more or less pale or colorless; organic *débris:* fibres of clothing or other house refuse. | Chlorine 4 to 7<br>Total solids 43 to 71<br>Ammonia 0.015 to 0.023<br>Nitrogen, as nitrites & nitrates 0.125 to 2.47<br>Total hardness above 17 |
| IV. Dangerous water. | Yellow or brown color; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste. | Bacteria of any kind; fungi; numerous vegetable or animal forms of low types; epithelia or other animal structures; evidence of sewage or ova of parasites, etc. | Chlorine above 7.14<br>Total solids " 71.4<br>Ammonia " 0.0225<br>Nitrogen, as nitrites & nitrates, above 0.026<br>Total hardness above 28.5 |

# CHAPTER VI.

## FOOD.

THE use of food is necessary to build up the body-structure, to repair waste, and to furnish force and energy for the proper action of all the organs, tissues, and parts of the body. In addition, certain substances are needed, not so much because they become a part of the tissue framework or yield kinetic energy directly, as that they are essential factors in the multitudinous chemical reactions and changes that are continually occurring within the living person. We may, accordingly, define a food as anything that tends to fulfil any one of these functions, provided it is not at the same time by nature harmful to the economy, and that it does not produce physiological effects out of proportion to its nutritive or metabolic activities.

Strictly speaking, this definition might include air and water, as the former is necessary to supply oxygen for union with other foods or with the tissues themselves, and the latter is needed to assist in the solution and assimilation of food-stuffs, to maintain the fluidity of the body-juices and to moisten the tissues effectively, to preserve roundness of form, and to flush out and remove from the system those waste matters and excrementitious substances whose retention gives rise to the symptoms of certain autogenetic diseases. But they are not usually included in the category of foods, and, having already been considered, they may be passed over in this connection with but incidental reference here and there.

If we classify foods according to their chemical composition, we may separate them into the following main divisions: 1. Proteids and albuminoids; 2. Carbohydrates; 3. Hydrocarbons or fats; and 4. Salts, extractives, etc. Each group is subject to different digestive and metabolic processes, and each has usually a different office within the body; for experience and careful experiments both show that all of these different food-principles are needed to sustain life and maintain health for any considerable length of time, and that, having them, nothing else except air and water is absolutely necessary; although what are sometimes called the accessory food-stuffs and many pleasant volatile odors and flavors are desirable and advisable adjuncts to the food proper, since they greatly favor its reception, digestion, and assimilation. But, though each class of food has its own special function in the economy of nutrition, in times of need or deprivation any one of the first three divisions may, in a way, supply the place of either of the other two.

Fothergill[1] epitomizes the use of the food-principles in this way: "The carbohydrates are the body-fuel, the surplusage being stored as fat; the albuminoids (proteids) serve to repair the tissues as they wear out; the salts form the blood-salts; the fat helps to build up normal health tissues, the excess being burnt as body-fuel. That is the real object of food."

While in the main correct, this is a broad statement of facts, and it needs qualification. For instance, just as there is some wear and tear in any mechanical machine while in use, which must eventually be provided for; so in the human body with its manifold activities there must be some destructive effect upon the body-structure and tissue framework, and it is to renew and replace this inevitable loss of material that a part—perhaps the larger or greater part—of the proteid food is taken. But we also know that in addition to this simple repair and replacement of tissue, "the presence of nitrogenized structure, and its participation in the action going on there, is a necessary condition for the manifestation of any vital energy or any chemical change," and we have reason to believe that, entirely apart from the idea of repair, proteid food is essential to the development and maintenance of this chemical and vital activity of nitrogenized tissue.

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[1] Manual of Dietetics, p. 5.

Confirming this, Pettenkofer and Voigt have shown that the absorption of oxygen is largely determined by the nitrogenous substances composing the tissues of the body, and that it is proportional to their size and vigor. Moreover, it is known that proteids may be, in part, converted into fat and possibly into other oxidizable substances, and thus become a source of body-heat and energy.

So, also, with the fats and carbohydrates. While they are not immediately nor entirely interconvertible, and while neither class may be permanently excluded from the diet, yet in emergency either may apparently fully supplant and substitute the other for a time, and we cannot yet say exactly how similar or dissimilar their service within the body is.

However, while Fothergill's epitome needs this emendation, known facts make it comparatively easy to gain a fair idea of the differences and functions of the proximate food-principles, to which end some help will probably be given by the following table:[1]

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[1] Notter and Firth, Treatise on Hygiene, p. 257.

### Properties and Functions of Food-principles.

| | Examples. | Functions. |
|---|---|---|
| Nitrogenous Substances. | | |
| **1. Proteids.**<br>All substances containing nitrogen of a composition identical with, or nearly that of albumin; proportion of N to C being nearly as 2 to 7 or 4 to 14. | Animal:<br>Albumin,<br>Fibrin,<br>Syntonin,<br>Myosin,<br>Globulin,<br>Casein.<br>Vegetable:<br>Glutin,<br>Legumin. | Formation and repair of tissues and fluids of the body.<br>Regulation of the absorption and utilization of oxygen. May also form fat and yield energy under special conditions. In most foods the above, both animal and vegetable, are largely converted into albumoses and peptones. |
| 1(*a*). Substances containing a larger proportion of nitrogen are apparently less nutritious.<br>Proportion of N to C about 2 to 5½ or 4 to 11. | Gelatin,<br>Ossein,<br>Chondrin,<br>Keratin, | These perform the above functions less perfectly, or only under particular circumstances. |
| 1(*b*). Extractive matters, such as are contained in the juice of the flesh. | . . . . . . . | These substances appear essential as regulators of digestion and assimilation, especially with reference to the gelatin group. |
| Non-nitrogenous Substances. | | |
| **2. Fats** (*or Hydrocarbons*).<br>Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogen into water.<br>Proportion of unoxidized H to C, about 1 to 7. | Olein,<br>Stearin,<br>Margarin, | Supply of fatty tissues; nutrition of nervous system; supply of energy and animal heat by oxidation. |
| **3. Carbohydrates.**<br>Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water.<br>Proportion of water to carbon, about 3 to 2. | Starch,<br>Dextrin,<br>Cane-sugar,<br>Grape- "<br>Lactin (or milk-sugar) | Production of energy and animal heat by oxidation; form fats and possibly some proteid. |
| 3(*a*). *Vegetable acids* (*and pectous substances*).<br>Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water. | (More O than is sufficient to convert all H into $H_2O$.)<br>Oxalic acid,<br>Tartaric "<br>Citric "<br>Malic "<br>(No excess of O.)<br>Acetic acid,<br>Lactic " | Preserve the alkalinity of the blood by their conversion into carbonates; furnish a small amount of energy or animal heat by oxidation. |
| **4. Salts** (*mineral*). | Sodium chloride,<br>Potassium chloride,<br>Calcium phosphate,<br>Magnesium phosphate,<br>Iron, etc. | Various; support of bony skeleton, supply of HCl for digestion, etc. Regulators of energy and nutrition. |

**Dietetics** means "a systematic regulation of the diet for hygienic or therapeutic purposes." It considers all the factors that affect the proper digestion and assimilation of food. For instance, it is not alone necessary to determine just what substances, in a chemical sense, the body needs to sustain life and maintain health. Nor is it sufficient to say that a man must have just so much of this and so much of that food, for there must always be a variation in both kind and quantity to meet the changing demands of the system. With a few exceptions, no matter how toothsome or healthful a certain food may be, it soon palls upon the appetite if necessity compels its continued use for a prolonged period, and this disgust may be so impressed upon the memory of the senses as to cause them to object to the use of that food forever after.

The æsthetic factors in the preparation and serving of food must also be taken into account, and the success in pleasing the taste and appetite has much to do with the progress and completeness of digestion. Other things being equal, palatable and agreeable foods are disposed of much more satisfactorily than others not so, and physicians and others should learn that especially in sickness the appearance and palatability of a food have much to do with its acceptance, not only by the patient, but by his stomach as well. Cleanliness and neatness of food, china, and napery are of greater value than expense or show, and a little attention and tact in such matters will often enable a patient to take, enjoy, and retain food and receive nourishment, even when he or she asserts and believes this to be impossible.

Another factor of much importance in the digestion of food, but one too often too lightly considered, is the mood or state of mind when the food is taken and while it remains in the alimentary canal. There is more than moral philosophy in maintaining a cheerful and a tranquil disposition during the daily meals and for a time thereafter; while there are numerous instances of most serious results occurring from the giving way to anger or other intense emotion at such times, the digestive functions being either completely checked, or, what is frequently worse, so altered that their products are toxic in character. And is not a dyspeptic often so because of his pessimism, rather than a misanthrope because of his indigestion?

Before proceeding further it will be well to consider briefly the physiology of digestion in so far as it concerns the chemical changes occurring in the food while it is in the digestive tract. These changes are brought about by the action of certain bodies secreted or elaborated by the digestive organs and glands, which we have been in the habit of calling unorganized ferments, but which would, perhaps, better be known hereafter as *enzymes*. Unorganized ferments are so called because they have not the definite cell-formation, life, and power of reproduction which belong to the yeasts, mould-fungi, and bacteria which bring about the fermentative changes in organic substances so commonly within the knowledge of everyone, such as the conversion of saccharine solutions into alcohol, of alcohol into acetic acid, etc.

But though unorganized, the enzymes likewise act upon organic matter; for example, upon the food which we eat, and—like the other ferments—they apparently do this simply by their presence rather than by entering into actual combination with the matter acted upon, as do ordinary chemical reagents. They are undoubtedly the products of glandular protoplasm, probably proteid in nature, and some, at least, very likely belonging to the group of nucleo-albumins, which latter form a component part of every organic cell.

The comprehension of the digestive functions will be greatly simplified if the student remembers that "with the possible exception of the coagulating enzymes, the action of the enzymes is that of hydrating agents: they produce their effect by what is known as *hydrolysis*—that is, they cause the molecules of the substance upon which they act to take up one or more molecules of water; the resulting molecule then splits or is dissociated, with the formation of two or more simpler bodies."[1]

Thus the insoluble proteids and carbohydrates become respectively the soluble peptones and sugars of their allies, capable of being absorbed into the myriad capillaries that are distributed throughout the lining membrane of the alimentary tract; and even the change that takes place in fat when digested is one that involves the taking up of some water.

There are four characteristics of the enzymes worthy of note: 1. That they are all soluble in water and glycerin, the latter being specially useful in making stable preparations of them from the organs producing them. 2. "That very low temperatures (0° C.) retard or suspend entirely their action, without, however, destroying the enzyme; that for each enzyme there is a temperature at which its action is greater," and that "in a moist condition they are all destroyed by temperatures below the boiling-point; 60° to 80° C. are the limits actually observed."[2] 3. "That they never completely destroy the substance upon which they act," probably being retarded by their products when the latter reach a certain percentage. "When these are removed, the action of the enzymes begins again." 4. "Except for very small quantities, it may be said that the amount of change caused is independent of the amount of enzyme present;" or, rather, "with increasing amounts of enzymes the extent of action also increases, reaching a maximum with a certain percentage of enzyme; increase of enzyme beyond this has no effect." The amount of work capable of being done by a small proportion of an enzyme is enormous, good pepsin, for instance, having the power of converting 2500 times its own weight of proteid; but we must remember that this power is not infinite, and that after a time the enzymes will cease to act.

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[1] American Text-book of Physiology, first edition, p. 219. [2] Ibid.

There are five groups or classes of enzymes concerned with the proper digestion of food to be found in the animal body, and it is interesting to note that examples of each of these classes are also to be found in various members of the vegetable world. The two principal remaining classes, being neither of animal origin nor digestive agents, need only be mentioned here: they are the *glucoside-splitting* and *urea-splitting* enzymes, the latter being produced by certain bacteria and converting urea into ammonium carbonate.

Considering the digestive processes in their order as the food proceeds from the mouth through the alimentary canal, we find that the first active secretion or fluid is the saliva, and that its enzyme is *ptyalin*, belonging to that group which converts the insoluble carbohydrates (starches) into soluble sugars, maltose, etc. Ptyalin acts best in neutral or slightly alkaline media, at about the body-temperature (40° C.), and upon cooked much better than upon raw starch.[1] Its action is retarded or totally checked by a low temperature or by strongly alkaline or moderately acid solutions, and the enzyme itself is probably destroyed by an increase in acidity equal to that of the gastric juice, or by a temperature of 65° or 70° C. The reason it converts cooked starch so much more quickly is probably because the heating process breaks up the cellulose envelopes upon which the ptyalin has almost no effect and which protect the starch granules within from its action. The heat also causes a very close union between the molecules of starch and water, this facilitating the later hydrolysis by the enzyme.

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[1] Kubel claims to have found that an alkaline reaction, even when very weak, actually interferes with ptyalin digestion, but that it is

In addition to its digestive function, the saliva also serves to moisten dry food so that it may be swallowed, and to dissolve sapid and savory substances that they may be duly appreciated by the organs of taste.

Our first hygienic lesson in regard to the digestive functions is, therefore, that in order to get the full benefit of the salivary secretions, all food, and especially that of a starchy nature, should be well masticated and retained in the mouth for some little time, instead of its being "bolted" at once or after a hasty bite or two. Nor should very cold or very hot beverages be taken at the same time with the food, for not only will the action of the ptyalin be thus retarded or destroyed, but that also, as we shall see, of the gastric juice within the stomach. A note here as to the drinking of water at meal-time will not be out of place. A moderate quantity of proper temperature will probably be beneficial rather than otherwise,

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favored by a weak acid reaction, especially if the acid be one of the stronger ones, like HCl. He admits that an amount of hydrochloric acid equivalent to that of the gastric juice checks the activity of the ptyalin, but believes that at the beginning of a meal and for a time thereafter salivary digestion takes place better in the stomach than in the mouth. Boston Medical and Surgical Journal, April, 1899.

since it helps in the solution of the food; but an excessive quantity tends to harm by diluting the enzymes too much, thus interfering with their reactions, and by interfering with the absorption of the digested matters.

The food, having passed from the mouth to the stomach, may still be acted upon for a time by the ptyalin until the work of the latter is checked by the acid of the gastric juice.[1] The energy of digestive action is then transferred from the starches to the proteid constituents of the food, the chief enzyme now being *pepsin*, though we also find in the gastric juice a coagulating ferment—*rennin*—which acts upon soluble proteids, like the casein of milk, to form clots or curds.

Pepsin acts only in an acid medium (the acidity being supplied normally by the free hydrochloric acid of the gastric juice), and best at the body-temperature. As stated, extremes of temperature are adverse to its activity and may check it altogether, and, likewise, too much or too little acid may have the same effect, from 0.2 to 0.3 per cent. of HCl being the normal amount and giving the best results. Rennin seems in the normal stomach to act only on the casein of milk, and curdles this probably because it is then more easily digested by the pepsin and, later, by the trypsin of the pancreatic juice.

The action of the pepsin plus the acid upon the proteids of the food is a hydrolytic one, and the end-products are practically hydrated proteids, called albumoses and peptones—substances especially diffusible and capable of absorption. The gastric digestion, therefore, after the action of the ptyalin has been checked by the acid gastric juice, practically has to do only with the albuminous or nitrogenous part of the food, the remainder, or at least that part of it not yet capable of absorption, remaining unchanged until it passes further on into the intestines. Soluble salts, sugars, and part, at least, of the peptones as they are formed, may, however, be taken up by the stomach capillaries, while the rest of the food-mass, kept ever in motion by the muscular movements of the stomach-walls, is being thoroughly mixed and converted by the peptic action into the semi-liquid substance called chyme, which is passed at intervals and in small quantities through the pyloric opening into the duodenum. Long before the stomach has entirely emptied itself—which may only be after several hours of activity—intestinal digestion is well under way, and in some respects this is the most important as well as the most comprehensive process of all. The three secretions to whose combined action the chyme is now subject are the pancreatic juice, the bile, and the intestinal juice. All are alkaline and quickly neutralize the gastric acid; it scarcely need be noted, then, that the remaining enzymes act best or only in alkaline media, though one of them, trypsin, may act in solutions not too strongly acid.

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[1] Recent experiments seem to show that "ptyalin digestion normally continues during the first hour of gastric digestion, or, in fact, until the hydrochloric acid secretion reaches the normal maximum." A. L. Benedict, Journal of the American Medical Association, July 28, 1900.

In the pancreatic juice we find three enzymes, practically the only remaining ones of much importance; although in the rather scanty intestinal juice two others have been found, one capable of converting starch into sugar, and the other of inverting cane-sugar into levulose and dextrose. The bile contains no enzymes. The pancreatic ferments are *trypsin*, which acts upon proteids and albuminoids even more powerfully than pepsin, and likewise converts them into albumoses and peptones;

*amylopsin*, which is practically identical with ptyalin in its function; and *steapsin*, which causes neutral fats to take up water and split into free fatty acids and glycerin.

Under the action of the trypsin all that portion of the proteid food which has not been completely digested in the stomach reaches that stage in the small intestine and is absorbed therefrom. In fact, it is very probable that the tryptic digestion is often the more important of the two. As the action of the saliva upon the carbohydrates, which form the greater bulk of our food, must of necessity be very limited, it is evident that almost all of the starch digestion is performed by the amylopsin, aided in slight measure by the similar enzyme of the intestinal juice. The salts and other soluble elements of the food have already been absorbed, and there remain only the fats or hydrocarbons.

Under the influence of the steapsin a comparatively small portion of the fat in the food is separated into glycerin and free fatty acids, and this action for some reason takes place much more rapidly when aided by the bile than with the pancreatic juice alone. Then these fatty acids unite with the alkalies and alkaline salts of the above secretions, but especially of the bile and intestinal juice, to form *soaps*, and these soaps aid in emulsifying the remainder of the fats and in thus making them ready for absorption, which latter process is also facilitated by the direct action of the bile upon the intestinal epithelium.

The student must not get the idea that the absorption of digested food from the alimentary canal is merely a physical process and a matter of osmosis or diffusion. Accumulating experience indicates that it is in a measure, if not largely, vital and physiological, and that "the living cells of the intestinal wall appear to take an active share in the process, and modify the action of the physical factors in a manner not at present understood." This is probably especially true as regards the absorption of the fats, whether we take the commonly accepted view that most of the fat is emulsified and only a small portion split up and saponified in the intestine, or the one which some have advocated of late years, viz., that almost, if not all, of the fat is decomposed and dissociated, and comparatively little, if any, emulsified.

The digestive processes having thus been outlined, it will be well to learn how they may be maintained as complete and perfect as possible. In the first place, the cooking of food is usually an essential preliminary. We cook meats not only to make them more agreeable to the palate, but also to facilitate digestion. The effect of cooking upon muscle (flesh) is "to loosen the bundles of fibrillæ from each other, so that they are readily torn asunder or crushed by the teeth," while the various connective tissues are softened and gelatinized, not only thus becoming more digestible and nutritious, but also allowing the histologic elements which they bind together to separate and be more freely acted upon by the solvent fluids. So with the vegetables, the heat and steam soften and rupture the cellulose envelopes of the various cells that the ferments may the more readily act upon their contents; and at the same time they bring about subtle chemical changes that greatly increase the palatability of food-stuffs.

Thorough mastication of the food is important for the reasons already stated, and the cause of most dyspepsias may be found in faulty habits of eating. Foster says that in the stomach "the natural bundles of meat and vegetables fall asunder, the muscular fibres split up into disks, and the protoplasm is dissolved from the vegetable cell"; but, "if the meat be not chewed properly, but 'bolted,' the solvent gastric juice can only act on the exterior of the mass, while 'lumps' offend the stomach and arrest the gastric secretion." The importance of abstaining at meal-time from beverages or other substances of too low or too high a temperature has already been noted, and, as all the enzymes act best at the body-temperature, care should always be had to avoid chilling of the abdominal organs while digestion is under way.

Again, as the formation and action of the enzymes begin with the ingestion of food and depend largely upon a sufficient blood-supply to the organs concerned as long as digestion continues, it is essential that the blood-current shall not be diverted from these organs during this period by excessive mental or physical demands, and that a condition of cheerfulness, repose, and rest should follow every meal. Regularity as to the time of meals and the avoidance of too great a tax upon any of the organs by over-indulgence or intemperance in eating are likewise both important matters and ones too often neglected.

It is interesting to note that in certain members of the vegetable kingdom are to be found enzymes very similar to the normal ones of animal origin just considered, and that where the latter appear to be deficient in quantity or action these kindred ones may sometimes be used with advantage. Thus, in the pineapple and in the papaw are ferments akin to pepsin or trypsin, and in the former another with the same action as rennin. All are familiar with the diastase of germinating seeds and its use in the making of beer; but not so common is the knowledge that other seeds contain fat-splitting enzymes much like steapsin. But though these extraneous digestants may be valuable and advantageous as therapeutic agents when an actual cessation of normal function makes them necessary, a caution should be interpolated here regarding the custom or habit that may be acquired of depending too much upon them, especially by persons, otherwise healthy, whose digestive functions are somewhat deficient. A better plan is to bring those functions up to the normal in strength and vigor by the observance of hygienic rules and a well-considered method of life.

**The Amount of Food Necessary to Life and Health.**—Considerable work has been done to determine just what amount of the proximate food-principles the average person requires daily, and in this respect Moleschott's tables are quite generally accepted, having been constructed from data gained by actual experiment and also by the continued observation of the effects of a number of dietaries. According to these tables, a man weighing 160 pounds and doing work equivalent to 300 foot-tons per diem will need about 4.6 ounces of proteids, 3 ounces of fats, 14.25 ounces of carbohydrates, and a little more than 1 ounce of salts. Vaughan believes that the average working-man in America requires daily, in round numbers, not less than *four* ounces of proteids, *two* ounces of fats, and *eighteen* ounces of carbohydrates.

It is essential that the proper proportion between the ingested nitrogen and carbon should be maintained, and this should be as *one* of the former to *fifteen* of the latter.

In addition, the individual needs from 70 to 100 fluid-ounces of water daily, a good part of which, however, is normally taken with the food. It must be remembered that the above figures represent only average amounts, and that climate, amount of exercise, the size and activity of functional and excretory organs, and personal peculiarities all serve to modify them in the case of any special individual.

Other conditions not interfering too greatly, any combination of foods giving the above amounts of the proximate principles at a reasonable cost will be an economical and healthful diet, provided such food is acceptable to the palate, is digestible, and contains nothing harmful to the system.[1]

Fothergill thinks that, as a rule, we take too much proteid food, especially in the form of meat, and that, though this goes in the main for tissue-repair, the latter requires much less of such food than we ordinarily suppose, and that the system does not need so very much of albumin or its equivalents. In this he may be correct to a certain degree, particularly as regards his fellow-Englishmen, who are notorious meat-eaters, and as to the facts that tissue-waste is comparatively slight and that the body framework rusts out rather than burns out. But in addition to the statements already made—that part of our nitrogenous food regulates the demand for oxygen, that part is doubtless a source of energy, and that still another part may be converted into fat—we should also remember that animal food is a concentrated food, that much energy has been expended in converting and storing it from the vegetable world, that it is stimulating, and that our digestive organs resemble more closely, at least as far as comparative weight is concerned, those of the carnivora rather than of the herbivora. These reasons, as well as the fact that proteids make up a considerable part of the only typically complete food that we have and which nature gives to the mammalian infant, indicate that we should be as careful not to use too little as too much nitrogenous food.

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[1] For such combinations, see Vaughan's Healthy Homes and Foods for the Working Classes; and Mrs. Abel's Practical, Sanitary, and Economic Cooking. Both are essays published by the American Public Health Association.

The proteid portion of our food is obtained from the albumin of meat and fish, from milk and eggs, and from the gluten of cereals and the vegetable casein (albumin) of the leguminous plants, such as peas, beans, etc. The proportion and properties of the albuminous matter vary, of course, in each of these, and even in the same substances under different circumstances; but all should be taken into consideration and used interchangeably if we wish to obtain the greatest variety and benefit in feeding, together with due economy of expense.

In this connection attention may again be directed to the notable fact that the leguminous plants, through the aid of certain species of bacteria, are able to absorb and store up in the form of proteids a considerable quantity of nitrogen from the surrounding atmosphere, and that these plants are, therefore, an important source of food-supply.

The carbohydrates that furnish food to the body and are one of the sources of the heat and energy upon which muscular motion and vital activity depend, are practically all derived, with the exception of milk-sugar, from the starches, sugars, and gums of the vegetable kingdom.

It has been shown that much the greater part of the digestion of carbohydrate food is due to the action of the pancreatic enzyme amylopsin; but we should not forget the action of the saliva, nor that thorough mastication greatly assists the subsequent digestion by breaking up the starch granules and exposing them more freely to the action of the digestive juices. The latter object is also obtained by crushing the cereals and by cooking the starch-containing foods, for "grinding and cooking lessen the labor of the jaws and salivary (and pancreatic) glands."

After the end-products (dextrose, levulose, etc.) of carbohydrate digestion have been absorbed from the alimentary canal, part of them, at least, are reconverted in the liver into animal starch or glycogen, and this portion becomes a part of the body-store of fuel. Fothergill says: "The liver stores up from each meal so much glycogen and gives it off as required; otherwise life would only be one dreary meal." Another and perhaps greater moiety of the digested carbohydrates is converted into fat and stored as adipose tissue in various parts of the body, as a further reserve of fuel for any emergency. "Many authorities state that fat is formed *directly* from carbohydrates, and the weight of evidence appears to favor this view; but whether it is so formed directly, or indirectly by retarding the metabolism of the fatty and proteid constituents of the food, there is no doubt that the consumption of carbohydrates results in the formation of fat within the body."[1] Moreover, "whatever the mixture of fats taken in as food, the fat of the body always has the same composition; this fact agrees with the conclusion that the metabolism and deposition of fat in the body are due to cell activity, and that the fat comes in part from the proteid and part from the carbohydrate foods."[2]

Another important function of the carbohydrate foods is the formation by their metabolism in the body of lactic and other acids, which are of the greatest value in nutrition and in maintaining the normal reactions of the body-fluids. This is perhaps one of the chief reasons why fats and carbohydrates are not interconvertible in any prolonged dietary.

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[1] Notter and Firth, Treatise on Hygiene, p. 254.

[2] Ibid., p. 253.

Fat is essentially a compound of glycerin with one or more fatty acids, usually stearic, palmitic, and oleic. The digestibility of a fat largely depends upon its being fluid at the body-temperature; therefore, as the melting-point of stearin is higher than this, the more of it that a fat contains, the less digestible and nutritious will the latter be. For this reason butter is more digestible than suet, lard than mutton-fat, etc., and the more assimilable cod-liver oil is that from which the stearin has been removed.

Fat for food is derived from vegetable as well as animal sources, many seeds and nuts and some cereals, as oats and corn (maize), containing much fat. By improved methods it is becoming possible to supply fats in purer, cheaper, and more agreeable forms, so that they may now be freely used even by the poor, the very class that needs them most.

Under normal conditions it is probable that the body-fat or adipose tissue is almost never derived from the fat in food, but rather, as stated, from the proteids and carbohydrates; but fat is also an essential part of tissue-structure, making up more than one-fifth of the solid matter of the brain and nerve tissues and one-sixth of muscle, and possibly serving as fuel when the cell-contents are oxidized; and it is not impossible that this fat of active tissues may come in part from that ingested as d. The writer has already hinted at the possibility of mbination of the newly absorbed fat with the argon he atmosphere in the lungs and the consequent formaof new cells or vital material. In any case, however, s a very important part of a man's diet, for not only is a small quantity necessary to the digestion of proteids, causing the formation in the body of larger amounts of fat than the quantity ingested and greatly improving the physical condition; but it may be and, when occasion requires, undoubtedly often is used directly as fuel without first being stored in the tissues.

As fat is a concentrated fuel-food, it is to be used freely when we want to keep the body warm or when we need extra force for any increased exertion. "On a diet rich in fat great muscular effort can be undergone with but little destruction of muscular tissue, and without increased urea discharge." The object of fat in the diet, then, may be said to be to give heat and energy as fuel, and, when necessary, to aid in the repair or building up of active tissue.

The constructive property of fat is especially valuable in the treatment of all wasting diseases, especially phthisis. Fothergill emphatically declares that "the great food for the strumous is fat," and also says: "Whenever there is any tendency to tubercle the individual should learn to eat fat, just as a seafaring man learns to swim. As a physician to a chest hospital, I have learned to dread the announcement that fat is no longer taken, especially if the individual is of strumous build, with a small, narrow chest. In my opinion, the existence of a considerable area of affected lung where the digestive powers keep up is less fraught with evil and less prognostically significant than intractable wasting with very little disease in the lung." In this connection, note that an excess of proteids in the diet causes a more rapid oxidation of fat, and that an excess of fat or of carbohydrates lessens the absorption of oxygen and the oxidation of both fats and proteids. Also, that the free use of fluids is thought to favor an increase in the quantity of fat deposited in the body.

Fat is practically indigestible in the stomach, and some stomachs cannot tolerate it, especially when taken with other food; although usually a little fat assists in the digestion of proteids by stimulating the secretion of the gastric juice. Cases occur not rarely in which it is necessary that comparatively large quantities of fat should be ingested and yet in which there is apparently decided gastric intolerance of it. In such event success is often to be attained by giving the fat some little time after the regular meals, when the gastric digestion is approaching completion and the chyme is being passed out of the stomach to be further subjected to the action of the intestinal digestants. It may also be well to emulsify it partially or wholly, especially if there be faulty secretion of bile and pancreatic juice, and sometimes to disguise its taste with agreeable aromatics or flavors. In this way there is generally but little trouble in administering fats, even such as those which, like cod-liver oil, have a disagreeable taste and odor. Failing in this, we may still resort to inunctions, preferably of predigested or emulsified fats, and often with considerable advantage, since it has been experimentally shown that after passing through the skin fat may be taken up by the subcutaneous lymphatics and later be oxidized or metabolized almost as completely as if it had entered the system by way of the intestinal canal and thoracic duct.

Certain salts in definite proportions are necessary for the maintenance of health in the body. "Lime, chiefly in the form of phosphate, is absent from no tissue, and there is reason to think that no cell-growth can go on without it." Even the bacteria must have earthy phosphates for the purposes of growth. Chlorine, derived largely from the sodium chloride of food, is necessary to form the hydrochloric acid of the gastric juice, the chlorides also keeping in solution the globulins of the blood and body-fluids and helping to dissolve the albumin. Phosphorus is necessary in the formation of the lecithin of nerve-tissues, as well as for the phosphates above mentioned, and those of potassium, magnesium, etc., which go to form bone. Potassium salts maintain the alkalinity of the solid tissues, and sodium salts that of the body-fluids. Iron is essential for the construction and nutrition of the blood-corpuscles, though small quantities of it are to be found in almost every other tissue.

But not only must the above inorganic salts be given in proper supply, but also certain ones of organic nature, in order to prevent conditions of malnutrition or disease. Those especially which are changed to form carbonates, as the lactates, tartrates, etc., or their respective acids, help to maintain the alkalinity of the system and appear to be most essential, as a scorbutic condition seems to be inevitably created or fostered by their absence. There is also some evidence that certain gouty conditions may be due to the removal of the natural vegetable salts by improper methods of cooking. The fact of the carbohydrates being an important source of these organic acids and salts has already been mentioned.

Lastly, with many of our foods we require the addition of certain flavors, condiments, etc., which, though they have little or no real food-value in themselves in the sense of repairing tissue or furnishing energy, do much good, when not abused, by making the food more palatable, by stimulating the secretion of the digestive fluids, and by acting as carminatives. These condiments should not be omitted from the food of the sick or convalescent, for they have a value of their own, and are "agreeable to the palate and, in moderation, good for the digestive organs."

As a review of the preceding statements, the following quotation, from Notter and Firth,[1] may be of value:

"With regard to the necessity for all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of proteids, fats, salts, and water. But special conditions of life, such as great exercise or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such a diet. It has not yet been shown that men can live in good health on proteids, carbohydrates, salts and water, without fat.

"The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the proteids causes a more rapid oxidation of fat, while an excess of fat lessens the absorption of oxygen and hinders the metamorphosis of both fat and albuminous tissues. The carbohydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

"It is generally admitted that the success of Banting's treatment of obesity is owing to two actions: the increased oxidizing effect on fat consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of starches.

"Health cannot be maintained on proteids, salts, and water alone; but, on the other hand, it cannot be maintained without them."

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[1] Treatise on Hygiene, p. 256.

It will be impossible to go into details concerning all the articles commonly used as foods, but there are certain facts that should be well known and which cannot properly be omitted from a work of this kind.

**Milk** is a typical food-stuff, complete in itself, in that it contains all the food-principles, and these in nearly the proper proportion, at least for infant life. The casein and albumin represent the proteids; the cream, the fats; and the lactose or milk-sugar is a concentrated carbohydrate—all being in combination with sufficient salts and water.

Milk should constitute almost the sole food of infants during the earlier months of life; and that it is capable of sustaining adult life almost indefinitely, especially where there is little demand for heat or the expenditure of force, has been shown in numerous instances.[1] Coplin and Bevan mention the case of a patient who lived and thrived on milk alone for over thirteen months, and of another who lived for three years on the same diet. But the limited proportion of carbohydrates, even though concentrated, is not all-sufficient for the maintenance of great vital activity, and for persons in ordinary life some addition to the diet is necessary.

The albumin of milk is coagulated by heat, but the casein, which constitutes the greater part of the proteid element, is clotted by an acid or by an enzyme, such as rennin; and as both of these are present in normal gastric juice, it would seem that the preliminary coagulation of casein was essential to its proper digestion. It should be remembered, however, that the casein of cows' milk forms a much harder and firmer clot than does that of human milk, and that the former should, therefore, never be hastily introduced into the stomach in large volumes, but should rather be taken slowly and preferably with other food which will help to divide the curd mechanically. In the feeding of children, an alkali, such as lime-water, is thought to soften the curd when mixed with the milk, and possibly to facilitate digestion.

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[1] It is understood, of course, that in order to be a proper food for young infants, cows' milk must be modified so as to resemble human milk as nearly as possible, and so as to give the proportion of the respective food-principles which each particular case may need.

Outside of the body, fermentative changes due to certain bacteria may convert the milk-sugar into lactic acid, which coagulates the casein and "sours" the milk. Another peculiarity of casein is the tenacity with which it holds large quantities of phosphate of lime, one of the most valuable of food-salts.

Sometimes it is advantageous or necessary to predigest milk for infants or sick persons, but if the digestion be carried beyond a certain point, the consequent peptones and albumoses will give the milk a bitter and disagreeable taste. In the feeding of infants it must not be forgotten that the percentage composition of human milk is different from that of cows' milk, and that the latter will need dilution to decrease the proteid proportion, but an increase of fat and carbohydrates. As a child grows older and more active, it becomes necessary to add to the milk additional carbohydrates, which should be easy of digestion and soluble, milk-sugar and predigested starches in the form of maltose and its allies being preferable.

Milk should always be kept as cool as possible and in closed vessels, not only to prevent the absorption of disagreeable odors and harmful gases, which it is very prone to do, but to exclude dirt and bacteria as well. As it is an excellent culture-medium, and as it is commonly liable to be exposed to contamination by organisms from many sources before it reaches the consumer, fermentative or other harmful chemical changes are almost certain to occur in it if the temperature conditions are at all favorable. For this reason it is necessary that the greatest care should be used in the handling of the milk from the time it leaves the cow until it is used, and, for the feeding of children and whenever there is any possibility of it being the carrier of disease germs of any kind, it should be properly sterilized and then kept sterile until used. In fact, sterilized milk, modified to resemble the human secretion, will usually be superior to any other artificial food for infants, but the sterilization should always be done before fermentation has begun and harmful products have been developed in the milk. The sterilization may slightly alter the taste and other properties of the milk by coagulating the albumin, but it is doubtful whether it makes any real change in its digestibility.

The cream of milk is fat in its most digestible and acceptable form, and should not be removed from milk if the latter is to be used as food. If the milk seems to be too rich, it may be advisable to skim it, giving it in some form or other with the regular meal, and reserving the cream until a couple of hours or so later, when gastric digestion is approaching completion. One may also often avoid the use of cod-liver oil and similar fats by taking cream—either plain or whipped and flavored—in this way some little time after the meals.

Skimmed milk and buttermilk may be used freely as beverages, as both are refreshing and healthful with some little food-value; buttermilk is also acceptable to many persons on account of its lactic acid. "Koumiss" and "kefir" are both prepared from milk through the action of certain fermentative organisms, which also bring about a partial digestion of the casein. Each contains carbonic and lactic acids, though in different proportions, some peptones or albumoses, and a very little alcohol. They are wholesome, agreeable to most palates, and are usually retained and utilized by stomachs rebellious to almost all other foods.

Milk may be a factor in the causation of disease in a number of ways. Large and tough curds of cows' milk in the stomach often cause mechanical irritation and indigestion, especially in young children, and the products of the fermentative action already referred to are a frequent source of serious intestinal disorders; while if further decomposition occurs, a very poisonous ptomaïn, called tyrotoxicon, is apt to be developed and to cause even fatal results to those using the milk. This same substance is also liable to occur in any milk-product, such as cheese or ice-cream, and is usually the cause or agent in the cases of poisoning by such products that are so frequently reported.

Again, the active principles of plants which the cow has eaten may be transmitted by the milk and produce their physiological effects. But a graver question is whether disease may be transmitted directly from the animals to man by this almost universal food-stuff. Every one knows that the milk from sick cows may cause marked disturbance of health, and there is fair evidence that cattle are subject to certain diseases identical with or very similar to human maladies, the milk serving as a carrier for the contagium.

Scarlet fever and diphtheria may be mentioned as diseases suspected of being transmitted in this way, and there seems to be no longer any doubt in regard to tuberculosis. Though some authorities still question whether this latter disease can be thus transmitted unless the milk-glands themselves are affected, the great prevalence of the disease among cattle and experimental evidence both make it certain that milk is often the means of transmitting the infection, and many believe that by far the larger number of the many cases of infantile tuberculosis have origin from this source. The condemnation and destruction of all cattle that show symptoms of tubercular infection is certainly one of the most important and effective methods of checking the spread of and eliminating this very prevalent and deadly malady. The use of inoculations of *tuberculin* as a means of diagnosis has materially contributed to this end, for by its aid the presence of the disease is often indicated in many animals that have as yet evinced no physical signs of the disease.

Milk, like other food-stuffs, may also become a disease-carrier through infection from dust and disease germs, especially in the vicinity of places where infectious matter is allowed to dry, become pulverized, and to be taken up into the atmosphere by winds and air-currents. But a more common danger is through carelessness in handling by infected persons or by the admixture with it of water containing disease germs. Epidemics of diphtheria, scarlet fever, typhoid fever, and cholera have all been traced to a contaminated milk-supply, and it is a question whether many of the more or less local outbreaks in cities are not of this character. The writer is personally cognizant of five cases of undoubted scarlet fever that occurred almost simultaneously in one locality and in which, apparently, the only common source was the milk-supply.

He was unable to discover that there had been any illness either among the cattle or in the family of the milkman in question, but he has always felt that there was considerable evasion in replying to the inquiries made.

Experience is also rapidly accumulating that infecting germs are implanted upon or in many foods by house-flies, roaches, and other insects, as well as by larger vermin, and even domestic animals, such as dogs and cats. Typhoid bacilli having been obtained from the bodies of flies from a house where eight cases of typhoid fever had occurred, further experiments showed that flies fed with these germs are able to convey them to other objects for as long as twenty-three days afterward. The bacilli have also been found on the heads, legs, and wings of flies five days after, and in their intestines nine days after such feeding.[1] Consequently, every effort should be made to protect food-supplies of all kinds from such contamination by insects and vermin, especially in time of epidemics, for we should realize that though most of the cases of an epidemic may arise from a common source, such as a polluted water-supply, there will be numerous sporadic cases of which the infection has been transmitted as above.

The possibility of milk as a source of danger to health having been shown, the lessons to be had are these: that not only must there be the greatest care in the handling and keeping of milk until it is consumed, but there must also be frequent and careful inspection of the animals from which it comes and of their environment; that no milk from any diseased cow should ever be used as food; that wherever there is the suspicion or possibility of the milk being contaminated with disease germs, it must be thoroughly sterilized, and that any change from its normal condition should also forbid its use.

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[1] Ficker, Archives of Hygiene, 1903, xlvi., p. 274.

Fortunately, good milk can almost always be had so cheaply and readily that no serious hardship inures by the strict observance of these rules, and the public should be educated to demand as well as to pay fairly for pure milk from healthy animals, these matters being even more important than that the quality, as shown by analysis, should always be up to a certain standard.

Good milk in bulk should be opaque, of clear ivory-white color, should have no peculiar smell or taste nor leave any deposit on standing. Nor should it show any change in taste or appearance upon boiling, excepting the formation of the slight skin of coagulated albumin due to the heating. Details regarding the composition of milk and the methods for its examination will be found in the final chapter of this volume.

The addition of preservatives to milk is very common, and should be discountenanced, not only because they are usually added in quantities harmful or prejudicial to health, but also, and almost more important, because milk should be supplied to consumers in such a condition and stage as not to need the preservative, and the presence of the latter is therefore suspicious. The same reasons also justify the condemnation of the use of artificial coloring-matters. The chemicals commonly used as preservatives are boric acid, salicylic acid, and formaldehyde. Of these, the salicylic acid is probably most harmful, as the habitual ingestion of even a moderate quantity is apt to be deleterious to the kidneys. (See Chapter XIV.)

**Cheese** is a most valuable food-stuff, and, as a milk-product, may be considered at this time. Good cheese usually contains twice as much nitrogen and three times as much fat as the same weight of meat, but many persons apparently find it difficult of digestion and can eat but little of it. This is perhaps because the nutriment is so concentrated and because, as usually eaten, it forms in the stomach a tough or pasty solid lump into which the gastric secretion cannot penetrate. Mattieu Williams has remarked that we habitually use cheese in the conditions in which it is most indigestible—either in its raw state or cooked into a leathery mass—and he asserts that if the cooking is such that it is thoroughly mixed with other articles of food, or if it be masticated with other food, so that this commingling of particles takes place, it will be found to be quite digestible by almost every one. He also advises the addition of a small amount of potassium carbonate in the cooking, as this favors solution of the casein and replaces that salt which is removed in the whey. As a food, only cheese made from whole milk, or from that to which extra cream has been added, satisfies all requirements, and skim-milk cheeses are decidedly less nutritious than those having the full proportion of fat.

**Butter**, consisting as it does largely of the fat of milk, is a highly nutritious article of food and one of the most digestible of its class. It should be pure, sweet and free from rancidity, and while some of the substitutes offered in its stead are entirely wholesome, they should never be sold as butter or used to adulterate it. Neither should butter contain an excess of water nor of casein, as its food-value, weight for weight, is thereby accordingly lessened.

**Eggs** yield almost their full weight of food in a concentrated and very digestible condition, and are valuable on this account, as well as for their palatability and their value in the preparation of many dishes. Although containing practically no carbohydrates, they have sufficient food-material in themselves for the complete development of the living chick, with the aid of nothing external except the oxygen which passes through the shell: the lack of the carbohydrate element, ordinarily one of the essential food-principles, is supplied by the heat from the mother hen or incubator, which is sufficient for the development and maintenance of the vital processes, since the unhatched creature wastes almost no energy in physical activity.

The white of egg is almost pure albumin with a little water and some salts; the yolk contains about 30 per cent. of fat and some albumin. The albumin coagulates at about 170° F., but if it is exposed to a still higher temperature for any but a very short period of time, it becomes hard and difficult of digestion. A so-called "soft-boiled" egg is scarcely more difficult of digestion than an uncooked one, and is certainly more palatable to almost every one.

Eggs, milk, and cheese may be made into many nutritious and palatable combinations which furnish food especially agreeable to the sick, as well as to those whose appetite and digestive functions have not been impaired.

**Meat.**—Good meat, when deprived of its contained water, is a concentrated food, and is used not only on account of the large amount of nutriment it contains, but also for its rich and agreeable flavor. It represents much vegetable matter converted into its present palatable and more digestible form by the metabolic activity of the animals from which it came. It contains all the essential food-principles, the carbohydrates, however, being present as muscle-sugar or inosite and, as in milk, in very small proportion. In all fresh meat there is much water, but more in lean than in fat meat; fat bacon contains 60 per cent.; lean beef, from 75 to 78 per cent. of water. As the proportion of fat increases, the quantity of albuminoids or proteids decreases: thus, lean beef may have only 2 per cent. of fat to from 20 to 24 per cent. of proteids, while bacon has about 24 per cent. of fat to 15 per cent. of proteids.

Of the varieties of meat commonly used, beef is the most nutritious. Good beef should not be too pale nor too dark, should show no blood-clots, have almost no odor, be elastic and not soggy to the touch, be well marbled with clean, white fat, and have compact flesh. Dark beef indicates that the animal was not properly bled, or has had some febrile disease; wet and flabby meat, that it is approaching decomposition. The flesh of young animals is more tender than that of older ones, but not so digestible, partly because the young flesh cannot be so thoroughly masticated and the fibres so well separated. Therefore, veal is not so digestible as beef, nor lamb as mutton. "Young flesh is less stimulating and nutritious and more gelatinous than that of the adult." (Vaughan.) Veal should not be too pale, as that indicates ante-mortem bleeding or too young an animal. The calf should be at least one month old before the killing.

Mutton is more digestible than beef, but not so nutritious. Its flavor is objectionable to some. Pork is an economical food for the poor man, as pigs of good stock store up three times as much of the food they eat as does the ox. The flesh is also easily preserved by drying or smoking, and ham and bacon are exceptions to the rule that dried meats are more indigestible than fresh ones. Again, pork fat furnishes much heat for cold weather by its oxidation and combustion in the body. But it must be remembered that it requires good digestive power to dispose of it, and that much pork is not to be advised for those of sedentary habits; also that certain parasites are especially liable to infest the tissues of the pig and to be transmitted thence to man.

The flesh of poultry is acceptable to most palates, if not too old and tough. White meat is more digestible than the dark, but not so nutritious or rich in flavor, since the latter is more highly nitrogenous. Chicken broth is more nutritious and more laxative than that made from mutton.

**Fish** is not sufficiently stimulating to constitute the chief flesh diet of a people, but it furnishes variety, and on account of its contained phosphorus should be used largely by those subject to neurosal affections. White-meated fish are more delicate in flavor and more easily digested, but not so stimulating as those of red flesh. Some fish are poisonous, either by nature or from inhabiting foul waters; while any fish may become so if undergoing decomposition. Shell-fish are particularly liable to develop poisonous ptomaïns in the process of decomposition, and, consequently, only such as are absolutely fresh should be used.

Oysters and clams which have been taken from a water contaminated by sewage may also convey the germs of infectious diseases, such as typhoid fever; an instance of this having been demonstrated in the investigation of an epidemic of the latter disease in Connecticut, which was reported by Prof. Conn, of Wesleyan University.

"The following meats should not be eaten: 1. The flesh of all animals dead of internal diseases, or which have been killed while suffering from such diseases, or animals killed by overdriving. 2. The flesh of animals with contagious diseases that may be transmitted to man. 3. The flesh of animals that have been poisoned. 4. The flesh of animals with severe infectious diseases, as pyæmia, etc. 5. Flesh that contains parasites that may be transmitted to man. 6. All putrid flesh."

Competent inspectors are appointed by governmental and State authorities to examine the various meats offered for sale in large cities, and undoubtedly do much good in preventing the sale of meat that is unfit for use. Unfortunately, from false ideas of economy in many communities, the authorized inspectors are too few in number to be able to attend to all the work that should be done by them.

Coplin and Bevan give the following as diseases which are to be specially guarded against: In cattle, epidemic pleuro-pneumonia, foot-and-mouth disease, contagious typhus, anthrax, tuberculosis, actinomycosis, Texas fever, dropsical affections, and indigestion. In sheep, braxy, variola ovina, black quarter, phthisis, fluke disease, and gid. In swine, anthrax, hog cholera, measles, and trichiniasis.[2] It should also be remembered that the intestinal parasites, such as tape-worms and round-worms, often, if not usually, gain entrance into the system through the ingestion of meat containing them in their embryonal or larval stages.

Therefore, in cooking meat, every part should be heated to at least 160° F. sufficiently long to destroy any disease germs or parasites it may contain, as very rare meat may still harbor these organisms in a living state. Tuberculosis, for instance, may be incurred by eating flesh imperfectly cooked, since its germs are quite resistant; though it must be said that this disease is not so likely to affect the

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[1] Gerlach. [2] Manual of Practical Hygiene, 1st edition, p. 132 et seq.

muscular tissues of an animal as are others of the maladies mentioned. The development of ptomaïns in flesh may also make it quite poisonous, and this is especially likely to take place in meats that have been kept for a long time after killing or in those preserved in cans or other packages that have been imperfectly heated or sealed.

Meat is also cooked to improve it in appearance and to make it more agreeable to the palate and to aid digestion. As already stated, the effect of cooking upon muscle-tissue is "to loosen the bundles of fibrillæ from each other so that they are readily torn asunder or crushed by the teeth." Perfectly cooked flesh is more savory than that which is either underdone or overdone. Meat cooked before *rigor mortis* sets in may be tender; cooked during the *rigor*, it is tough and is masticated with difficulty; after the *rigor*, it is more likely to be tender when cooked than at any previous time.

In cooking meat, the ultimate condition in which we wish it to be should always be kept in mind, and pains should also be taken not to overcook or use too high a temperature. The processes pursued in making a palatable soup or broth, and in cooking meat so that it may retain all its juices, salts, and flavors, are radically different. In the first case, it is desired to extract as much of the soluble constituents of the flesh as possible, and to do this the meat should be cut into small pieces and allowed to remain for a time in cold water, this afterward being very gradually raised to a temperature of about 160° F. In this way the juices exude and the salts and soluble parts of the meat are dissolved before the pores are closed by the coagulation of the albumin. On the other hand, if it is desired to retain the juices and savor in the meat, the piece should be as large as possible that the surface exposed will be small in proportion to the volume. The meat is to be first subjected to a temperature as high as possible that the surface may be cooked at once and the albumin coagulated, the juices being thus prevented from escaping by the sealing of the pores. In boiling, this end is attained by plunging the meat at once into boiling water; in roasting, by having the fire or oven very hot. After this first heating it is best to lessen the degree of heat somewhat, that the subsequent cooking of the interior may go on more slowly and the temperature within may not rise above the coagulating-point and make the fibres hard and stringy. Meat cooked in this way should be tender, juicy, and rich in flavor. Broiling or grilling is, of course, but a modified roasting.

Soups and broths made of meat-juices alone and without the addition of other substances are stimulating rather than nutritious, as they contain little albumin, carbohydrates, or fat. However, if certain vegetables be added to the soup, the latter will gain sufficient of these food-principles and be highly nutritious, and such vegetable soups are of great value in all schemes of economic cooking. Bones are also of value on account of the salts, gelatin, and other soluble organic matter which they contain, and used with vegetables they make especially nutritious and easily digested soups.

The meat from which soup has been made, on the other hand, is not all that is desirable, for though it still contains albumin and fat, it has lost its salts and savoriness and is unpalatable, and therefore not easily digested. It needs something—a sauce or condiment, or preferably a meat-extract, for meat-extracts are nothing but thin soups evaporated to dryness or condensed. Or, if both soup and the meat be taken at the same meal, the things lacking in each are supplied by the other, and the needs of digestion and nutrition are supplied.

Frying meat, as it is commonly practised, should not be tolerated, as it renders the albumin of the flesh extremely tough, besides soaking it with fat or grease and thus greatly increasing the difficulty of its digestion. But frying by total immersion in boiling fat is an excellent way of cooking meats containing much water, and especially fish, for the boiling-point of fat or oil is very high and the meat is instantly cooked on the outside, while the water in the interior, being converted into steam, prevents the ingress of fat by its expansion, cooks the albumin, and leaves the flesh in a light, flaky condition. But the fat must be boiling hot when the meat is immersed, and the latter should not be allowed to remain in the former longer than just suffices for perfect cooking.

Beef-tea as ordinarily made is only a thin extract of beef, the stimulating properties of which will be considered hereafter. To make a beef-tea containing any considerable amount of nutriment, the meat from which the juices have been extracted should be dried, pounded fine, and all fibrous and tendinous portions removed. This pounded beef should then be added to the liquid extract, as then only is it really a food. Moreover, the mixture should always be seasoned, even for the sick, that it may be thoroughly acceptable to both palate and stomach. In making the extract, remember that the meat should be cut into very small pieces and added to cold water in about the proportion of one pound of lean meat to one pint of water, and that the whole should be brought to the boiling-point very slowly.

**Cereals.**—The cereals form one of the most valuable kinds of food. All but rice contain considerable proteid matter—from 10 to 20 per cent.—beside carbohydrates, which predominate, some fat, and a goodly proportion of phosphates. Rice has only 5 per cent. of proteids to 75 per cent. of starch, but it is easily digested, and is therefore a valuable food for the young and the sick; it is also well fitted as a chief food for dwellers in hot climates on account of its low heat-production.

Wheat is the most nutritious cereal, and bread made from it is aptly called "the staff of life," since it is a food which, with the addition of a little extra fat and albumin, furnishes the essentials in proper proportion for the support of life. Barley closely resembles wheat in composition, and rye also is rich in nutriment, though perhaps a little more difficult of digestion than wheat. Oats are valuable on account of the large amount of fat they contain—over 5 per cent.—beside a full share of proteids, starch, and salts. But ordinary oat-meal needs vigorous digestive functions, and where the latter are lacking it is often productive of intestinal disturbance and irritation. Corn or maize, though not a true cereal, furnishes a valuable food with considerable fat; it also contains a vegetable fibrin. The proteid constituents of the cereals are vegetable albumin, casein, and gluten, the last of these being most abundant in wheat and perhaps of the highest food-value.

Grinding breaks up the grain and the starch granules of the cereals, aids in separating indigestible parts, and renders the starch much more suitable for cooking. Wheat flour ground by the old method should be soft and smooth, but that made by the new roller-process is more apt to be slightly granular. It should not be too white, as that indicates a lack of the proper proportion of gluten, and should contain everything but the outer husk of the grain. The inner coats should be retained in the flour, as they hold a considerable part of the gluten and practically all of the grain salts. Corn-meal should be dry and powdery, or at least not too granular. Flour of any kind should be kept well covered in a dry place, and should contain no living organisms nor any adulterants.

**Bread** is practically made of flour, water, and salt, though sugar, milk, etc., may be added to improve the flavor. As flour and water alone make a tough and indigestible mass, bread is leavened to make it easier of mastication and digestion, and for this purpose either yeast, baking-powder, or aëration is employed. Yeast at the proper temperature rapidly converts some of the starch or sugar into carbon dioxide and alcohol, the former of which in escaping makes the dough porous and light, the walls of the cavities it produces being kept from collapsing by the tenacity of the gluten until the heat fixes them permanently. As the heat of baking dissipates both the gas and alcohol, from 10 to 12 per cent. of the weight of the flour used is lost by this method. Moreover, if the fermentation goes beyond a certain point, lactic and acetic acids are formed and the bread becomes "sour." Consequently, it has been advised that the yeast method be discarded, and that the leavening be done by means of baking-powders or aëration. Carbon dioxide is evolved from the baking-powders upon the application of heat and moisture, and the bread is made light by the gas, with no loss of food-substance, and, if the powders are pure, with nothing harmful added to the bread. There should be no alum or other adulterants in baking-powders nor in the flour itself. Alum unites with the phosphates of the flour, rendering them insoluble and preventing their absorption from the alimentary tract. Bread may also be leavened on a large scale by forcing air or carbon dioxide under high pressure into the dough, or by mixing the flour with cold water heavily charged with the latter gas. In this method, also, there can be no loss of food-material nor any detriment to the bread, provided cleanly precautions are observed.

Good wheat bread should be almost white, light, sweet, spongy, and with a crust easily broken and equal in bulk to about one-quarter of the loaf. As considerable of the starch has been converted into dextrine in the crust, the latter is more easily digested than the interior of the loaf. Fresh bread is not nearly so digestible as that which is a day or two old. As stated, bread needs only a little added fat and albumin to make it a perfect food, the former of which at least is almost if not quite sufficiently supplied in the butter which is commonly used upon it.

**Vegetables.**—The vegetables in common use are valuable articles of food in that they give us the larger portion of carbohydrates and also furnish an agreeable variety from day to day. In the fresh state they contain considerable water—from 75 to 90 or 95 per cent.—the residue being mainly one or another of the carbohydrates. Potatoes exemplify this well, since they contain but little proteids and fat, and practically all of their solid matter is starch. On account of their customary cheapness and ease of growth and storage they are usually considered to be a valuable article of food for the poor man, but it should not be forgotten that other foods which are apparently more expensive may at times be actually cheaper than potatoes, both on account of containing those principles which the latter lack and because they require less expenditure of digestive energy. (See chart, page 258.) Beets contain much sugar and are nutritious, palatable, and easily digested. Onions have considerable sulphur, and should be used freely when its need is indicated. Cabbage, cress, and other greens are especially valuable for the organic salts which they contain, and because they serve so well as relishes. Spinach is said to contain more assimilable iron than any other article of food commonly used. Celery and lettuce are nerve sedatives, and asparagus acts as a diuretic and is thought to be of special benefit to the kidneys.

The seeds of the leguminous group of plants, such as peas, beans, lentils, etc., contain from 22 to 25 per cent. of proteid matter in the form of vegetable casein, and almost 50 per cent. of starch. It is on account of this abundance of food-matter that they make such a valuable addition to soups and the like, and for the same reason they should also be used in any dietary where economy of expense is a factor. Green peas and beans are much more digestible than those that have ripened and dried, though, of course, they do not yield so much nutriment, weight for weight, as the latter.

All vegetables should be so cooked as to retain their salts, or else the water in which they are cooked and which contains these salts should be used in making soup or broth, to be served at the same meal with the vegetables. This is especially advisable with regard to potatoes and sweet potatoes, as their soluble salts have much to do with their digestibility. It is for this reason that a properly roasted potato is always better than a boiled one, and that steamed vegetables are both more palatable and more digestible than those which have been cooked under water. In fact, Mattieu Williams has even suggested that possibly one reason why gout is so prevalent among Englishmen is because they habitually eat boiled vegetables and throw away the water in which these have been cooked. The salts not only help in the digestion of the starches, but they furnish bases to unite with and render soluble the irritating acids that produce the gouty symptoms. It should also be remembered that the dried legumes should always be softened by soaking in water before cooking, and that they as well as other vegetables should be cooked, whenever possible, in soft water.

Prepared starches, such as arrow-root, tapioca, sago, etc., are easily digestible, and therefore useful especially in the preparation of food for the young and the sick.

**Fruits** are especially valuable on account of their flavor, acceptability to the palate, benefit to the digestion, and for their laxative action. Ripe fruits may be eaten freely: in most cases preferably early in the day. Fresh fruits are usually better than those dried or otherwise preserved; but where the former cannot be had, the latter should be used freely, and all should be used throughout the year whenever possible. Green fruit, or that which has begun to decay, should not be eaten, for obvious reasons.

**Nuts** are nutritious on account of the high percentage of fat that most of them contain, but are difficult of digestion unless thoroughly masticated. Recently pastes made from various nuts have been placed on the market, and are to be considered as an agreeable addition to our dietaries.

**Adulterants and Preservatives.**—Much might be written concerning the adulteration and sophistication of food-stuffs and of the addition of more or less harmful preservatives to food of a perishable nature. That the first is carried on to an enormous extent seems certain. The remedy appears to be in the passage and enforcement of stringent laws and the maintenance of frequent and rigid inspection by both State and governmental authorities, in the dissemination of information as to the adulterations practised and the means of detecting them, and in the utmost publicity and exposure in the case of transgressors.

As to the use of preservatives, the very extensive sale of these in localities where they would be most likely to be added to food indicates their employment, as does their continual discovery by direct analysis. In Birmingham, England, such preservatives were found in 20 per cent. of 2300 samples of food examined, and boric acid in 5 per cent. of 1360 samples of milk. Such substances as boric acid, salicylic acid, and formaldehyde are commonly used, though it is frequently stated that more dangerous ones, such as hydrofluoric acid, are occasionally employed. And though it should in fairness be stated that it is possible that, if only the minimum of such substances as boric acid and formaldehyde necessary to prevent putrefactive or fermentative changes in food be used, no harm to the human economy will result,[1] yet it is undoubtedly wiser to condemn the practice of adding chemical preservatives of any kind to food. There are two reasons for this: 1. There is no surety and very little probability that the minimum quantity of preservative consistent with safety to health will not be exceeded in most cases through carelessness or recklessness. 2. That foods that apparently require such preservatives should be supplied to the consumer before the deterioration in them has begun, or else they should be sterilized by the more costly but safer employment of heat.

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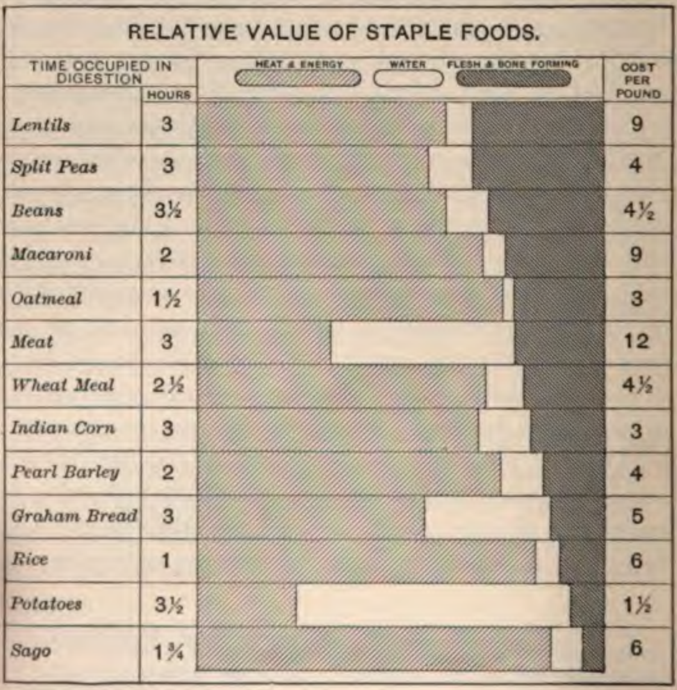
[1] Rideal and Fullerton (Public Health, May, 1899) arrive at the following conclusions: 1. Boric acid (1 to 2000) and formaldehyde (1 to 50,000) are effective preservatives for milk for twenty-four hours. 2. These quantities have no appreciable effect upon the digestion. 3. These quantities have no appreciable effect upon the digestibility of foods prepared with them. 4. Formaldehyde in the proportion given above, so far as their investigations have extended, does not appear to have any injurious action upon animal tissues or nutrition.

The following diagram may be of service in determining the value of certain food-stuffs:

Fig. 46.



# CHAPTER VII.

## STIMULANTS AND BEVERAGES.

THE essential function and property of stimulants is to liberate some of the latent force of the body, and they are of use and value in sudden emergencies, to tide the system over important crises, to hasten a tardy convalescence, or perchance to whip up a flagging digestion so that it may the better prepare food for the repair of waste or the supplying of body-fuel. Those stimulants, excluding drugs, with which we are most concerned are of three classes, viz., nitrogenized vegetable stimulants, such as tea and coffee; nitrogenized animal stimulants, as beef-tea and meat-extracts; and alcohol. All these are "force-liberators," and though alcohol may sometimes act the part, in more moderate measure, of a "force-producer," it is well to remember that they give scarcely anything at all to renew or replace the energy which they set free. This being so, care should always be taken that some food be supplied during or shortly after the stimulation produced by the agents in question, in order that the body may have a new store of force to replace that which has been liberated. Especially is this necessary in cases of sickness; and as the soluble carbohydrates furnish fuel and consequent heat and energy to carry on the vital processes, these even more than other kinds of food are to be supplied, and will generally be well received and utilized by patients or others in need of stimulation. Again, just as we must not depend on stimulants alone to the exclusion of food, so also must we take care not to continue their use any longer than is necessary to attain our object, and likewise must not overstimulate or carry the action so far that the body is left poorer and weaker in force than before the use of the stimulants began.

For example, beef-tea constantly stimulates the vital and nervous functions to greater activity, this requiring that either tissue or food be oxidized to produce the necessary energy. The stimulating factors in ordinary beef-tea are the meat-extractives, such as kreatin and kreatinine, which are products of the wear and tear of life, intermediate between living, active tissue and the final excretory matters, such as urea and uric acid; hence they can have little, if any, real food-value. Beside these the beef-tea contains only the salts of the meat, which, though valuable, are not force-producers. Therefore, unless food be otherwise supplied, the body-tissue must be consumed, and the result must eventually be in the end disastrous; and yet this is what occurs to many patients through the mistaken idea that beef-tea is both nourishing and stimulating. When "whole beef-tea" (the recipe for which is given on page 251) is used, these remarks do not apply, since it contains some true food, though even here soluble or readily digestible carbohydrates may wisely be added.

The active principles of the nitrogenized vegetable timulants resemble very closely in chemical composition ot only the meat-extractives, but also those drugs, like trychnine, which are used in medicine as tonics and cerebrospinal stimulants, and they act physiologically in a similar though milder manner.

As beverages, tea, coffee, and cocoa supply fluid for the system and that stimulation of the assimilative functions that causes a sense of comfort after their use, cocoa and chocolate having also the advantage of supplying some food. But these beverages may all be abused in their use as readily as may beef-tea or alcohol, and "tea-drunkards" and "coffee-drunkards" are not uncommon in hospitals and in private life. The teacup is not always the one that "cheers but does not inebriate." Women especially who drink much tea are apt to be nervous and dyspeptic, to have the "tea-drinker's heart," and to suffer from headaches and neuralgias. They depend upon tea to take the place of nutriment, and soon use up what little store of force they may have had, since they fail to replenish it with fuel-food. Men are more addicted to the use and abuse of coffee, and often manifest symptoms directly traceable to such intemperance. While caffeine increases heart action, and may be used to advantage in cases of cardiac debility, for the same reason it should be taken with caution and in moderation where the cardiac action is already too vigorous. Vogel has advised the use of strong coffee with sugar and cream as a tonic and food in debility accompanying the acute diseases of children.

It is interesting to note that among all nervous, energetic people the use of some one or other of these stimulant beverages is common, and that "total abstainers" from alcohol seem instinctively to resort to tea or coffee. And while it is probably theoretically true that the healthy person would better abstain entirely from the use of stimulants, except in emergencies or at rare intervals, yet the almost universal desire for and use of them probably indicate that under our present high tension of living there is a real physiological demand and need for them that perhaps should be satisfied in a measure, but with moderation and judgment.

**Alcohol.**—Liebig says that "alcohol stands only second to fat as a respiratory material," but adds that "the same effect could be produced in the body by means of saccharine and farinaceous articles of food at one-fourth or one-fifth the cost." Fothergill also holds "that the chief portion of the alcohol ingested undergoes consumption in the body," but insists that "the question of 'alcohol as a food' can never be separated or divorced from that of 'alcohol as a stimulant' or as a force-liberator."

Much undue importance has recently been given to some scientific investigations that served to establish the fact that alcohol can be and often is almost completely oxidized in the body, and that it produces therein practically the same number of heat-units as when it is consumed outside. But the inference that it can therefore be substituted for and used with impunity in place of the usual carbonaceous foods is not justifiable, because the powerful physiological and ultimate pathological effect of the alcohol upon the higher nerve-centres and active tissues is ignored, because of the liberation of the body's latent force in excess of the energy which the alcohol supplies, and because even the above-mentioned investigations and experiments went to show that there was an actual detriment to the nitrogen-bearing tissues of the body during its use.

Again, Liebig writes that "the use of spirits is not the cause but the effect of poverty. It is the exception to the rule when the well-fed man becomes a spirit-drinker. On the other hand, when the laborer earns by his work less than is required to provide the amount of food which is indispensable in order to restore fully his working power, an unyielding, inexorable law or necessity compels him to have recourse to spirits. He must work; but in consequence of insufficient food a certain portion of his working power is daily wasting. Spirits, by their action on the nerves, enable him to make up the deficient power at the expense of his body; to consume to-day that quantity which naturally ought to have been employed a day later." This may also be the case where there is an abundance of food, but where it is improperly chosen for the needs of the individual or ruined by bad cooking. Education in the principles of the scientific and economical selection of food and its preparation may thus become a means of preventing those diseases that depend on or are aggravated by insufficient or improper food and consequent alcoholic excesses. The effect of alcohol upon the weak and savage races is much more marked and disastrous than upon the civilized and strong; so it harms the health of the underfed and overworked much more than it does that of the well-fed man of means and leisure, and affects women and children more than adult men. This latter point is to be remembered in practice.

Remember also that, while alcohol is partially a respiratory stimulant, it is a force-liberator and consumes the body-store, and unless given with other readily oxidizable food the risk is run of putting a patient "in a grave never dug by Nature," especially where there is already danger of the patient sinking from exhaustion. But it is just in these cases, when given with other food, that we find alcohol a valuable therapeutic agent. Give it with foods that produce heat and force—*i. e.*, some form of the soluble carbohydrates, as maltose, malt-extracts, milk, milk-whey, or even sugar. Where the assimilative powers are weak it may be advantageous or necessary partially or wholly to predigest these foods; but above all, remember to replace what alcohol takes from the body, or physiological bankruptcy will ensue. Note also that, though alcohol may be in one sense a food, it is a very costly one, and that intoxication must occur long before a man could get the equivalent of a full meal.

Alcohol is to be used in sickness practically to sustain the vital powers, to meet emergencies, and to lift the patient over obstructions in the road to health; and such use requires a thorough knowledge of its action coupled with the highest judgment.

In malt liquors there is usually considerable maltose, thus combining with the alcohol a soluble carbohydrate of the highest value, and these brewed ales, etc., may often be used with benefit as tonics, especially where convalescence is protracted. The stronger distilled liquors are diffusible cardiac stimulants, and are especially valuable in emergencies, but the continued use of them must only be advised with great caution. Fothergill gives two excellent rules for the use of alcohol by the healthy: "First, never have alcohol in the brain when it has work to do; second, a little alcohol betwixt a man and past trouble is permissible; but it is not well to put a little alcohol in front of a coming trouble." Murchison, in his work on *Fevers*, lays down these rules for practice, which it would be well for all to adopt: "What are the conditions of the animal economy in which alcohol may be of positive use? That there are such conditions, I believe cannot be denied by any one who has honestly studied the subject; but they are not the conditions of perfect health. It is especially when the circulation is weak or sluggish that a daily allowance of alcohol may do good. Thus: 1.

Alcohol is useful in the course of most acute diseases when the organs of circulation begin to fail, as they are apt to do. A moderate quantity usually suffices. The large quantity still sometimes administered may do harm by inducing congestion of internal organs. 2. In convalescence from acute diseases or from weakening ailments, when the circulation remains feeble and the temperature is often subnormal, alcohol is useful in promoting the circulation and assisting the digestion. 3. In persons of advanced life the circulation is also often feeble, and a moderate allowance of alcohol often appears to be beneficial. All other conditions of the system marked by weakness of the muscular wall of the heart, whether permanent or transient, are usually benefited by alcohol." Alcohol is a good servant, but a bad master. King Chambers says: "Let alcohol be taken never as a stimulant or preparative for work, but as a defence against injury done by work, whether of mind or body. For example, it is best taken with the evening meal or after toil. Let the increase in the desire for and the power of digesting food be the guide and limit to the consumption of all alcoholic liquids. Let the forms be such as contain the least proportion of fusel oil. Let all with an hereditary tendency to hysteria or other functional diseases of the nervous system refrain from its use altogether, even though as yet in good health."

**Beverages.**—To comment individually upon the multitude of non-alcoholic and non-stimulating beverages that are now more or less generally used, is both impracticable and unnecessary, nor will any attempt to classify them be of much value. For the most part they serve only to please the palate; though if in this way they bring about a greater ingestion of fluids when these are needed, their service cannot be considered a vain one. For it has already been stated that an ample supply of drinking-water or other fluids taken daily and habitually is essential to the satisfactory removal of the various waste matters from the body, and that without it the latter may readily develop conditions favoring disease.

Moreover, it is true that certain gases and salts held in solution in some beverages, such as mineral waters, increase this excretory action, and may be highly beneficial in appropriate cases; but it should be a matter of caution that where such therapeutic results are thought to be necessary, competent medical advice should be the guide as to the kind and quantity of the agents used. This comment is justified by the fact that of late many substances possessing decided physiological power have been advertised and sold in the form of one beverage or another directly to the laity, who, being incompetent to judge as to whether or not such substances are actually needed in their individual cases, may do themselves much harm in this way.

Only such beverages, then, as are quite simple in their nature or as are advised by competent medical authority should be used. If they are artificially made and water is the solvent fluid, as it will be in most cases, there should also be certainty that it comes from a clean and safe source, lest it carry the germs of disease. There is no doubt that frequently the cheaper bottled drinks which are dispensed so generally are made from water that has been liable to more or less dangerous pollution, and there is the additional risk that arises from the imperfect cleansing of the bottles for these liquids which have been returned to be refilled. A little thought as to the dangers which do exist in relation to this matter will be convincing as to their gravity.

Many of the most popular beverages are charged with carbon dioxide under compression, and the fact that so much of this gas can be taken into the system in this way without apparent harm, and its free elimination, would seem to be additional evidence that it cannot in itself be so very harmful in the atmosphere, even when in proportions considerably greater than the normal.

In conclusion, it may be said that a free use of all such beverages as are known to be clean, safe, and wholesome will probably be found to be entirely favorable to health unless there be some contraindicating reasons peculiar to the individual himself; and that their substitution, whenever possible, in place of the alkaloidal and alcoholic stimulants is to be commended on hygienic as well as other grounds.

# CHAPTER VIII.

## PERSONAL HYGIENE.

THE proper consideration of this subject demands an ample volume rather than the limits of a single chapter, for the ultimate aim of all sanitary work is the preservation and betterment of the health of the individual, and beside, the factors that affect the well-being of the person are so multitudinous in their number and in their phases that no brief discussion can comprehend them all.

However, much that pertains to personal hygiene and that requires no repetition for its application has already been given in the preceding pages; so that it is hoped that if the reader will exercise that virtue of common-sense and reflection that is so essential in this study, the remarks to be added will be helpful in suggestion and in answering many questions, even though they may not be considered in any way as complete discussions of the respective themes.

Each age has its own requirements, and that which may be entirely satisfactory or permissible at one time may not be so at another. To attain the best results it will often be necessary even to anticipate with prophylactic measures the birth of the child; and broadly speaking, much of the welfare of future generations lies in the care of those now living.

One of the gravest sociologic problems of the day is as to how far the State is justified in restricting or preventing the propagation of the defective or degenerate of the human race; and though the time may not be ripe for the law to take positive action in these matters, it is the duty of every sanitarian to use his utmost efforts to the end that only the healthy and the normal may continue.

The advances in physiologic and biologic science in recent years have done much for all humanity, but in no respect, perhaps, have they been of more service than in determining the great influence of environment and in establishing the fact that the presence or absence of disease is oftentimes, if not always, due as much to the predisposing conditions and physical status of the individual as to external and exciting causes. What may cause only a trifling ill in one may bring about most serious evils in another whose environment is not so fortunate.

Life has been defined as the power of an organism to adjust continually its internal conditions to its external conditions, and as long as this is done satisfactorily life persists. The secret of personal hygiene and health, then, must lie in determining the relationship between the internal and external conditions of the individual's organism.

"Know thyself" is advice good for the body as well as for the mind or soul, and knowledge of the right kind can do no harm. He who knows his personal and physical nature and acts accordingly is well equipped to fight against the ills of life, and the study of the relationship above referred to will help the thinking man so to care for himself that in all probability his days will be prolonged.

But a caution or two must be interpolated here. It is well known that "expectant attention" too persistently directed toward a certain organ may lead to decided alterations or disturbances in the functions of that organ; and again, unless one well understands the mysteries of human physiology, a little imperfect or insufficient information in this respect may lead to the assumption or pursuit of habits and practices actually dangerous to health. Too much ill-advised care and attention may be just as full of risk as too little, and physiological egotism without a sound basis may have a bitter reward.

What is needed is that each one should study carefully the phenomena of his daily life, should determine accurately the purpose and reason of each of the respective functions, and then, not forgetting their interdependence upon one another and that all should work in harmony, should endeavor to do that which will best facilitate the functional activity with the least expenditure of energy.

There are a number of ways in which the study of personal hygiene may be advantageously pursued, but for practical purposes one of the best is to consider it with respect to the main groups of organs and functions of the body, keeping always in mind, however, the correlation of these, and that no part of the body can be entirely independent of the rest.[1] Nevertheless, the hygiene of infancy is a study by itself, for it is in that epoch of life that the plastic constitution can be and is moulded most readily by all the influences of the environment, whether for good or evil, and it is at that time that salutary efforts are to be made with most hope of success and eventual good.

Moreover, the principles of personal hygiene may be more readily taught to and inculcated in the young, but with much greater difficulty can we affect the mature or aged; for we are all creatures of many habits, and in the mature adult the impress of these may resist to the utmost any and all endeavors to modify or remove them.

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[1] This method has been followed in Pyle's Manual of Personal Hygiene, to which the reader is referred for an admirable discussion of the subject, which must be treated all too briefly here. The writer would also recommend Starr's Hygiene of the Nursery to all who desire specific and authoritative information concerning the young.

Too much stress cannot be laid upon the fact that it is the constitution, the nature of the inherent tissue, that controls or modifies the inception of many of the ills of life, and that whether this in its normal and highest vigor be a bequest of heredity or be attained only by the most careful attention to details in the practice of the art of hygiene, it should always be looked upon as the most valuable physical possession of the individual.

To state again what has already been written: "The essence of sanitation is to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body pure and free from depressing factors."

With this preface, the following discussions are added in the hope that they may be of assistance in determining the way of right living and in securing the welfare and health of each individual.

## Heredity.

In the broadest sense heredity is a characteristic jointly possessed by two cells, furnished by respective parents, which join and form a fused cell, which carries on its evolution under certain governing impressions indelibly stamped by the two parental lines of descent; but, in the ordinary use of the term, it may be defined as the transmission to the offspring from parent or ancestor of a trait, type, temperament, characteristic, or predisposition which has a governing or influencing effect upon the growth or nature of that offspring. This transmitted impression may be either for good or for evil.

"It shows an incorrect conception of the law of heredity to look for a return of identical phenomena in each new generation."[1] Also, "we do not mean exclusively by heredity the very complaint of the parent transmitted to the children, with the identical symptoms, both physical and moral, observed in the progenitors. By the term heredity we understand the transmission of organic dispositions from parents to children."[2] In true hereditary disease the faulty conditions must be transmitted in the *germ-plasm*, and not be due simply to accidental factors affecting the embryo during its fœtal development.

Consequently, as hygienists, we must use the influence and power that we have to further the transmission of beneficial or elevating characteristics only, and to prevent the bequest of harmful influences and hereditary diseases to the generations to come. "The germ of the unborn infant must be complete and untainted in all its nature, otherwise we cannot hope for a vigorous and perfect growth or development."

As the family is the foundation of the State, and society is a congregation of men for the purpose of acquiring greater power and more comforts through mutual co-operation, the latter, whether domestic or civil, has some right to make men understand that they must care for the health of the generations to follow, and to enact reasonable laws looking to the prevention or obliteration of transmissible infirmities. And history seems to show that no great nation has ever been destroyed or overwhelmed until its people had first neglected or abused the laws of hygiene, heredity, and sociology.

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[1] Moreau, Psychologie morbide.

[2] Morel, Traite des Dégénérescences.

**Marriage.**—We find that a married couple have generally, beside themselves, the welfare of five human beings within their keeping. To produce healthy children and ones not prone to disease, both parents should possess good constitutions, and they should take great care not to weaken these by excesses of any kind, physical or mental, nor, as far as lies in their power, by any chronic disease. It is evident that children of parents that have been conscientious observers and followers of Nature's laws must have a better chance for health and superiority all their lives.

In this climate the proper age for marriage is considered to be about twenty-four or twenty-five for the man, and nineteen or twenty for the woman, though this must vary with the state of development of the parties concerned. Some of both sexes mature at a considerably earlier period than do others, and it would be unjust to say that they were not fit for the duties of marriage till they reached the age of slower-growing ones. Usually, however, before the ages given development is not complete and the whole organism is in a transition state. We know that the use of any organ before it has attained its complete growth or development is very apt to cause exhaustion, or perhaps premature degeneration of that organ, and we cannot but believe that children developed in immature sexual organs must be deficient in vital force and energy. It is often noticeable that a child apparently strong and vigorous may have but little power to resist disease or may even be strongly predisposed to some infirmity; in such cases there will likely be some defect or taint in the parent stock.

Distinguishing characteristics are more likely to transmitted in the early married life of parents, because their organs and forces are then more vigorous; but if a couple marry when quite young and before their own organs are fully developed, their elder children may be more deficient, mentally and physically, than their later ones.

Late marriages are not likely to be so fruitful as earlier ones, possibly owing to the increased difficulty of parturition on the part of the mother and her consequent unwillingness to undergo the ordeal more than a few times. But healthy middle-aged persons, who have married late, may have even healthier children than those who have married too early.

In features, constitution, sense-organs, shape of head, etc., the child is most apt to resemble the father; while it will likely follow the mother in the shape of the trunk and in the formation of internal organs. The character and mental qualities of the child may come from either parent or from both. Maternal impressions during pregnancy undoubtedly often have a marked effect upon the coming infant.

So also do maternal toxæmias or other depraved conditions of the mother's system, though occasionally such influences do not apparently have such a marked effect as we would anticipate. There may even be actual and direct infection of the child through the placenta. In fact, "intrauterine infections and modifications of the fœtus are more frequent and more important than conditions of true inheritance of disease."[1]

**Inherited and Congenital Diseases.**—Hereditary influences are generally transmitted directly from parent to child, but we occasionally find a cessation of a trait or predisposition for one or more generations and then a recurrence. To such a peculiarity we give the term *atavism*. "A family history of less than four generations has only a limited value."

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[1] McFarland.

A disease may be truly congenital—that is, existing at birth and transmitted directly from parent to offspring—as syphilis, scrofula, etc.; or there may be only an inherited predisposition to the disease, as toward tuberculosis, etc. Physicians have thus a twofold duty: first, to do all they can to guard against the transmission of such diseases; second, to combat the disease or any tendency to it as soon as the first symptoms thereof are discovered or it is suspected in the child. The first duty can be accomplished, theoretically, by preventing generation and production on the part of those unfit to produce healthy offspring, and practically, within certain limits, by fighting the causes and their effects in the parent individual, especially at the ages or times when these have the greatest force or are most apt to manifest themselves. For the second, the child must be immediately placed in the most favorable hygienic surroundings, and everything possible done to prevent the further development of the disease or predisposition. In many cases such early interference will accomplish much good, and the disease may be averted entirely. Especially is this true of those inheriting the tuberculous diathesis.

Too often the child of a tuberculous parent is exposed after birth to the same conditions that served to develop the disease in the parent, and its inherited predisposition to the malady is intensified by the environment of a damp and undrained soil, a dark and unventilated house, etc., and by insufficient or improper food until infection is all too easily acquired, and the child that might have been saved becomes an early victim of the ignorance, carelessness, or neglect of those who should have fostered it with extremest care and solicitude. On the other hand, the apparently complete eradication of the transmitted predisposition from many children whose inheritance has been as bad, but who were promptly removed from the unsanitary environment of their birth, shows how much this one influence may work for good.

The most important of the hereditary or transmissible diseases are syphilis, tuberculosis, scrofula, cancer, gout, hysteria, epilepsy, certain physical deformities, certain skin diseases, insanity, and criminal tendencies of various kinds. But do not forget that what may appear to be a direct and actual inheritance of a disease may only be the production of the disease in that person by the same agents, environments, and morbid conditions as caused or favored the disease in the parent. However, even here there is very possibly a transmitted predisposition to the acquirement of the disease, rendering it all the more easy for it to manifest its symptoms upon slight provocation. Therefore, there should be no marriage between persons inheriting predispositions to the same disease, especially if they be relatives, and "a person affected with hereditary or well-marked constitutional syphilis, or having a strong consumptive taint, or tendency to mental unsoundness, should not marry at all."

Defective eyesight is very apt to be transmitted to children, and the latter should be carefully examined and, if necessary, fitted with proper glasses before being placed at school or at any work requiring much use of the eyes.

Infirmities which do not prevent marriage from being fully accomplished, or which do not tend to the degeneration of the offspring, are not good reasons alone for forbidding marriage, but all that have such a tendency are.

A man should not marry a woman too far advanced in life, nor one that is very feeble, delicate, or deformed, especially as to the chest or pelvis. Hysteria, convulsions, and epilepsy due to organic disease should prevent a woman from marrying, though some extremely nervous and hysterical women are much benefited by marriage and have healthy children. So with many women who have uterine congestions and displacements before marriage.

Evidence seems to indicate that marriage between relatives is reprehensible, and that the danger increases with the nearness of the relationship, since the children of such marriages are prone to disease and to defects in the sense-organs, especially the eye and ear, or in mental qualities. But upon closer investigation it is probably more nearly true that "the objection to consanguineous marriages lies not in the bare fact of the relationship (of the parties concerned), but in the fear of their having similar vitiations of constitution." Few families or persons are absolutely healthy or free from taint, and "it may safely be asserted that when both parents are possessed of a physiologic or pathologic congenital characteristic, that characteristic is almost certain to be repeated in an aggravated form in the offspring."[1] We can, accordingly, easily understand that "in consanguineous marriages the real danger is in the strong probability that both parents have some distinct taint of degeneration, which is liable to be increased in their children, but which might possibly disappear if each married a person not bearing the same or some closely allied character. The marriage of two individuals of the phthisical type, whose families were strangers to each other, would be as productive of evil as the marriage of first cousins who were phthisically inclined."[1] However, any advice on the subject must depend upon the special circumstances in each case, but chiefly on the health and degree of relationship between the parties.

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[1] Lawrence Irwell, Philadelphia Medical Journal, July 21, 1900.

## Exercise.

Exercise is generally considered to mean simply the action of the voluntary muscles, but it has a wider meaning than this. Every organ in the body is capable of being exercised in some way or other; and if not properly exercised, an abnormal state is almost certain to ensue. "Life is organization in action." Each organ has its own special stimulus, and if this be normal in amount and character, we should have health. Also, the trained use of an organ makes it more effective in the performance of its functions. But deficiency in exercise favors a lack of nutrition, wasting in size, and eventually degeneration of tissue; while, on the other hand, too much work may favor hypertrophy and tissue degeneration.

Proper muscular exercise is highly beneficial to health, and in the end actually necessary to the proper performance of functions in other organs; it is consistent with and necessary to health. But, to be of value, the exercise must not only be regular, but must also consist of movements of sufficient force to necessitate energetic contraction of the muscles; we must do work. This necessitates resistance as an element, and we may define physical exercise as *voluntary labor*. We need the resistance to obtain the proper contraction of the muscles, the contraction for their disintegration, the disintegration for their renewal, etc.; for we know that upon the constant destruction and disintegration of tissues depends their subsequent renovation, and that the strength and vigor of all parts of the body and of the whole depend upon its *newness*.

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[1] Lawrence Irwell, Philadelphia Medical Journal, July 28, 1900.

Beside the fact that proper physical exercise makes the voluntary muscles larger, harder, stronger, and more quickly responsive to the will, and that it increases the functional capacity of the involuntary muscles employed, it largely promotes health and strength by quickening the circulation and increasing the respiratory powers. During muscular action (contraction) there is a conversion of potential energy into motion, a call for more food, an increased demand for and consumption of oxygen, and an increased production of and elimination of carbon dioxide and other waste matters.

This increased demand for oxygen and elimination of carbon dioxide necessitate increased action of the respiratory organs—the lungs, and this is one of the greatest advantages of physical exercise. The respirations are increased in frequency and depth, the lungs expanded, the air vessels flushed out and refilled with each inspiration. Doubtless many cases of pulmonary tuberculosis could be prevented or cured if only people could be taught to take sufficient and suitable exercise and to breathe properly, for we rarely find the lungs fully expanded except in the outdoor worker or athlete. Consequently, the movements of any given exercise should be with speed and force sufficient to quicken and deepen the respiration; and, conversely, if any severe exercise is to be undertaken or a course of training begun, special care must be had to develop the lung capacity.

A man walking at the rate of four miles per hour inspires five times as much air as when reclining at rest, which latter amount is, for an adult, about 480 cubic inches per minute. Or, as Pettenkofer has shown, a man on a day of rest absorbs 25 ounces of oxygen and throws off 32 ounces of carbon dioxide and 29 ounces of water; on a day of work he absorbs 33.6 ounces of oxygen and throws off 45 ounces of carbon dioxide and 72 ounces of water. In other words, the elimination of carbon on a work-day is more than three-fourths of a pound.

Muscular exercise is necessary, therefore, for the proper elimination of waste carbon from the body, and, as the action of the muscles is checked and lessened if the carbon dioxide produced by their action is not immediately carried off by the blood and eliminated by the lungs, it follows that during exercise there should be nothing to impede the circulation or the action of the chest and lungs, and that all tightness of clothing, especially about the waist, neck, and chest, should be avoided. Moreover, inasmuch as the amount of carbon dioxide and other waste matters eliminated is so very much increased during exercise, a much larger amount of pure air is needed, and all rooms and buildings wherein exercise is to be taken should be well ventilated.

After exercise an increased amount of carbonaceous food and of water must be supplied to replenish the system for what has been eliminated. The increase of carbon food is probably best given in the form of fat rather than of the carbohydrates, though there is some difference of opinion on this point; and of all fluids, water is doubtless the best in ordinary cases for training. As a general rule, alcohol is harmful, because it benumbs and deadens the nerves and will, and because, as every voluntary impulse must originate in the brain, anything that interferes with the communication between it and the muscles must lessen the promptness with which they respond and the consequent efficacy of their work. The use of a small quantity of malt liquor, however, as a tonic or after the exercise is finished may not be harmful, but the decision as to its need or use should be left to the physician or trainer rather than to the one taking the exercise.

By exercise the action of the heart is increased in force and frequency, the pulse is made full and strong, if the work be not too excessive or sudden, and the flow of blood and other fluids is increased throughout the whole body. As long as the heart is not overtaxed the pulse-beats are regular and even, though suddenly increased exertion may make the rate very rapid. Ordinarily exercise increases the rate from ten to thirty beats per minute. Excessive exercise leads to palpitation and hypertrophy of the heart (one reason why any extensive training should be under a competent trainer); but, on the other hand, deficient exercise leads to a weakening of the heart muscle and heart action, and probably to dilatation and fatty degeneration. If at the beginning of a new exercise the heart action becomes irregular, rest should be taken, and the exercise then begun in a more moderate and gradual way. The heart stimulus is largely due to the increased amount of blood in its cavities, but it should be remembered that the venous circulation is chiefly due to the muscles. "Every muscle is a little heart," and these, by their contraction, constantly tend to drive the blood onward to the true heart and lungs.

Exercise greatly increases the amount of perspiration from the skin, this perspiration containing water, salt, and considerable waste matter. The evaporation of the water tends to keep the body cool, but on account of the great heat-production there is not much danger of chilling the body during exercise. As soon as work is stopped heat-production is checked, the body cools off rapidly, and then there is danger of chilling unless more clothing be added. Flannel is best for this purpose because it is a non-conductor of heat and hygroscopic and so prevents too rapid cooling of the body. Keep the skin clean so that the sweat-glands may be unobstructed in the performance of their functions.

Exercise increases the appetite, partly because of the increased demand of the muscles for food, and partly on account of the increased circulation of the blood through the vessels of the alimentary tract and the liver, this causing a more perfect digestion of food.

If exercise be taken too soon before meals, either the stomach, by calling the blood from the exhausted muscles, will prevent their proper repair and rest; or the muscles, calling the blood from the stomach, will prevent the proper formation of the gastric juice when food is introduced. If exercise be taken too soon after eating, it is apt to prevent the flow of blood to the organs of digestion and the formation of the digestive juices; or, by forcing the contents of the stomach into the intestines before gastric digestion is completed and before the food has reached a condition in which the intestines can make use of it, to cause intestinal irritation and indigestion.

Proper physical exercise favors a symmetrical brain development, for it not only sends more blood containing food and oxygen to this organ, but exercise of the functions of the centres governing the action of the muscles must also favor the growth and development of those centres. "Hand culture, apart from its value *per se*, is a means toward more perfect brain culture," and exercise by itself alone is truly educational, although this feature of it may be more fully developed and emphasized by proper systems and methods. The great trouble is that it is extremely liable to be misapplied, misunderstood, or neglected.

The aim of training should be to increase the capacity of the lungs and the breathing power, to strengthen the heart and the circulation, to invigorate the brain and nerve-centres, to improve digestion and nutrition, to make the muscles more powerful, more responsive to the will and their capacity for endurance greater, and to lessen the amount of adipose tissue. Systematic exercise also helps one to resist disease, because by it waste matters are carried off; pores, glands, and organs are kept at work and healthy, and active tissues take the place of weak and sluggish ones.

Fatigue is due to lack of contractile material in the muscles to continue work, to the exhaustion of nerve-force and motor impulses from the brain, and to accumulation of waste products, possibly leucomaïns, in the muscle.

Active exercise is that brought about by one's own movements; passive, that produced by something outside or collateral to one's own power.

It is hard to determine how much exercise any given person ought to take, as the personal equation varies so much. The average healthy man should probably do work equivalent to 150 foot-tons daily. The work of walking on a level at the rate of three miles per hour is said to be equal to that of raising one-twentieth of the body-weight through the distance walked. According to this, a man of 150 pounds in walking one mile does work equal to 17.67 foot-tons, and his total daily physical labor should be equivalent to walking about nine miles at the above rate to get the proper amount of daily exercise. This seems like an excessive amount, but if the actual physical work of one's customary vocation be taken from this, it will not leave so very much for the daily health-task; and while the natural disinclination of many to exercise grows stronger by indulgence, and while urgent reminders are wanting and the evils arising from the neglect, abuse, or misuse of exercise are not so very immediate or apparent, the latter are still certain to result, and are not at all consistent with good and perfect health.

### Bathing.

In health we make use of baths and bathing for the cleansing of the body, the stimulating of the functions of the skin, and as a tonic to the whole system. A suitable bath properly taken is exhilarating and thoroughly enjoyable. Baths are also to be employed in sickness as a means of cure, but such use of them is foreign to the present discussion.

H. C. Wood says: "Cleanliness and the maintenance of the proper condition of the skin require the use of the bath at least twice a week. In some very delicate persons the general bath produces marked depression, but this can almost always be avoided by the use of very hot water. If the hot or warm bath be employed habitually, it should be preferably taken at night, and, unless under very exceptional circumstances, the hot bath should always be followed by cold sponging or the cold shower-bath, or by a plunge into cold water." The temperature of a cold bath may be from 40° to 75° F.; a tepid bath, 75° to 85° F.; a warm one, 85° to 100° F.; a hot one, from 100° to 110° F. A cold bath is taken not so much for its cleansing as for its tonic and stimulating effects; the others are used mainly for their cleansing properties, though if followed by the cold sponge, shower, or dip, the sense of exhilaration produced will be marked.

Cold baths taken immediately after physical exercise while the body is still warm, but after perspiration has ceased, and followed by a good rubbing and friction of the skin, dispel fatigue and give a sense of buoyancy and lightness. The shock of the first contact of the water with the skin is but momentary, and can be withstood by most persons unless there be serious organic disease; and the reaction produced certainly compensates for the primary discomfort. If the bath be taken in the open air, there is the additional benefit of a plentiful supply of fresh air for the lungs, of the physical exercise and the increased circulation induced by swimming or combating the surf, and, if in the sea, of the stimulation of the skin by the salt water. In fact, sea-bathing may be advantageous to a marked degree where the circulation and action of the skin are sluggish.

Those who are subject to organic heart disease should not indulge in sea-bathing nor in deep fresh-water bathing where a sudden tax may be made upon the strength and the heart action be disturbed or checked. Women who are menstruating or who are in the later months of pregnancy should not take cold baths.

Baths should not be taken too soon after meals, because digestion may be lessened or entirely stopped by the blood being called from the stomach to the skin and muscles, and nausea and vomiting thus induced. "There can be no doubt that many of the cases that are called 'cramps,' and which frequently result in drowning, are due to this cause."[1] In cold baths the head should be immersed first, "to avoid increasing the blood-pressure in the brain too greatly, which might result if the body were gradually immersed from the feet upward."[2]

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[1] Rohé's Text-book on Hygiene.

[2] Ibid.

The following rules, issued by the English Royal Humane Society, are worth noting: "Avoid bathing within two hours after a meal, or when exhausted by fatigue, or when the body is cooling after perspiration. Avoid bathing altogether in the open air, if, after having been a short time in the water, there is a sense of chilliness, with numbness of the hands and feet; but bathe when the body is warm, provided no time is lost in getting into the water. Avoid chilling the body by sitting or standing undressed on the banks or in boats after having been in the water. Avoid remaining too long in the water, but leave the water immediately if there is the slightest feeling of chilliness. The vigorous and strong may bathe early in the morning on an empty stomach; the young and those who are weak had better bathe two or three hours after breakfast. Those who are subject to giddiness or fainting, or who suffer from palpitation or other sense of discomfort of the heart, should not bathe (out-of-doors) without first consulting their physician."[1]

After any kind of a bath the body should be thoroughly dried, not only to restore and accelerate the circulation of the skin by the friction and to prevent cooling by the evaporation of the water, but also to prevent chafing and eczematous eruptions where the skin is subject to the friction of clothing. Warm or hot baths should not be taken if the person is to be exposed to the cold within several hours, and the same rule applies to Turkish, Russian, or vapor baths; so the former had best be taken in the evening, and the latter should not be taken away from home, especially in cold weather, unless the bather rests for a time after the bath, and then wraps up well before going into the open air.

[1] See also Sea Air and Sea Bathing, by John H. Packard.

In all warm baths in health the principal object is to secure the cleansing effects, and to be effective their use must be systematic. The pores of the skin are self-cleansing only to a certain degree, and the free use of warm water is most beneficial in removing dry epithelium, sweat, dirt, and grease. If the pores of the skin are obstructed, there are not only irritation and eruptions of the skin produced, but more work is thrown upon the kidneys, and these, if unsound, will break down the quicker. Soft water is to be preferred for ordinary bathing and washing, because it often prevents or lessens cutaneous irritation, and because it saves soap.

A Turkish bath consists: 1. Of a dry, hot-air bath at a temperature of from 120° to 170° F., or even higher, for from ten to thirty minutes, which causes in most persons profuse perspiration with no sense of discomfort, but rather a pleasant sensation. After this come: 2. A hot shower-bath to wash off the sweat. 3. Shampooing, massage, and scrubbing to remove thoroughly all dirt, loose epithelium, and perspiration from the skin. These take place in moist air at from 100° to 110° F. 4. A warm shower-bath gradually changing to a cold one, and then a thorough drying of the body and a rest for a quarter or half an hour. A Russian bath differs from this only in that moist air at 150° F. or under is used instead of dry air for the first bath.

It has been said "that a person ought never to stay in either the hot-air or steam-room if in any wise oppressed, or to use very cold water afterward if one feels any shrinking from it." Nor should one who is very corpulent or who has organic heart disease take a Turkish or Russian bath without the advice of a physician. But for healthy persons they are quite pleasant and in most cases beneficial, provided they are not taken too often and that one does not indulge in them too long at a time.

The terms sun-baths, mud-baths, sand-baths, and pine-needle baths are self-explanatory. These are used in treating certain diseases, and are supposed to be especially beneficial in rheumatic affections.

### Clothing.

There is scarcely anything that can be said on this subject with which almost every one of ordinary intelligence is not in some respects conversant. According to Poore, the main objects to be sought in clothing the body are: "1. To maintain the temperature and, by preventing the loss of animal heat, to diminish to some extent the demands for food. 2. To allow the chief heat-regulating mechanism—*i. e.*, the evaporation from the skin—to proceed with as little hindrance as possible. 3. To allow all muscular acts the greatest possible freedom, and to avoid the compression of the body in so far as may be possible. 4. To protect the body from heat, cold, wind, and rain. 5. To disguise as little as may be the natural beauties of the human figure."[1]

The substances from which articles of clothing are usually manufactured are wool, silk, cotton, linen, leather, and furs, although almost everything that can possibly be fashioned to suit the needs or fancies of the wearer is or has been utilized for the purpose. Goods of all manner and kind are woven from the first four substances mentioned, either singly or in combination one with another, and felts are made from wool, hair, or fur, these latter being made, not by weaving, but by an interlacing and matting together of the fibres by pressure and rubbing.

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[1] Stevenson and Murphy, Treatise on Hygiene.

**Wool.**—In a general sense wool is probably the most valuable of clothing materials, since in a variable climate or where there are sudden changes of temperature it is the safest for the wearer to use. While, taking fibre for fibre, it probably does not vary so much from linen or cotton as a heat-conductor as is generally believed, it is usually woven in such a way as to entangle large quantities of air in its meshes, thus preventing either sudden lowering or raising of the body-temperature, since dry air is an especially good non-conductor of heat. Moreover, wool is very hygroscopic, readily taking up water and perspiration and giving them off slowly, thus reducing the cooling by evaporation to a minimum and regulating the heat-dissipation of the body. All who are subject to rheumatism or to such disturbances of health as are due to sudden temperature-changes should wear woollen garments next the skin the year round, varying the thickness and weight, of course, to suit the season; and children and others subject to digestive disturbances will usually be greatly benefited by the constant use of a woollen (or, in case that is too heavy, a silken) band about the abdomen.

As it is ordinarily woven, some persons cannot tolerate wool next the skin on account of its irritating properties. These latter are obviated, however, if the undergarments be made of pure wool woven by methods similar to that introduced by Jaeger, or of a mixture of wool or cotton, or by wearing a net garment of linen or cotton next the skin and underneath the woollen under-clothing. The Jaeger method, by the way, is said to provide for the escape of moisture from the material and for the free permeation of air through its interstices.

**Silk** is an excellent non-conductor of heat, and is almost as hygroscopic as wool, so that it is suitable material from which to make warm clothing. Its great natural beauty and the facility with which it takes coloring-matter also make it desirable from an æsthetic standpoint, while its great disadvantage is its high cost. For those who cannot wear wool next the skin and to whom cost is no objection, silk is an excellent material for undergarments.

**Cotton** is probably the most generally used for clothing of all the fibres. It is not so hygroscopic by far as wool, but it is hard and durable, and is, above all, cheap, so that it furnishes the bulk of the clothing for the masses. If smoothly woven and of a light color, it makes extremely cool garments for warm climates or seasons. On the other hand, if warm clothes are desired, the cotton must be woven so as to have large air-spaces in the fabric, thus making it resemble the ordinary woollen clothing in texture and partly in function, and should be of a dark color. Cotton should not be worn next the skin by those subject to sudden temperature-changes, nor during exercise, unless in the latter case it is changed immediately after the exercise or additional clothing is added to the body to prevent too rapid evaporation and cooling.

**Linen** is valued for its purity of color when bleached, and for its durability. It is more expensive than cotton, and its hygroscopic and heat-conducting properties are about the same as the latter. It is especially desirable for use in clothing for hot climates and for articles of dress that are easily soiled and need frequent cleansing.

**Furs** provide extreme protection against the wind and cold, both on account of the impermeability of the skin and of the large quantity of air entangled in the fur itself.

**Leather** is utilized for foot-coverings, etc., on account of its durability, pliability, and practical imperviousness to moisture, especially when oiled; and in cold countries is also used for body garments on account of its resistance to the wind and the efficacy with which it keeps the body surrounded with a layer of warm air.

With the possible exception of **rubber,** which is especially useful for the protection which it gives from wind and rain, other materials from which clothing is made need not be mentioned here, because of the comparative rarity of their use and their close resemblance to those already named. The value of any material for clothing purposes, however, may be said to depend upon the slowness with which it permits the passage of heat to or from the body and the evaporation of water, the amount of air its meshes contain, its impermeability to the wind, or else its special adaptability to some particular purpose.

Certain materials are manufactured from combinations or mixtures of two or more of the four fibres first mentioned, and it sometimes becomes necessary to distinguish these one from another and to determine the proportion of each in the goods. This is done by microscopical examination, each fibre having its own peculiar characteristics, and by chemical reactions. Some of these latter are as follows: Wool and silk dissolve in hot liquor potassæ or sodæ of a specific gravity of 1050, while cotton and linen are not affected. Wool and silk are stained yellow by strong nitric or picric acid; cotton and linen are not. Sulphuric acid affects wool but little, slowly dissolves silk, and changes cotton or linen into a gelatinous substance that is colored blue by iodine. Hot concentrated zinc chloride dissolves silk, but not wool; and copper dissolved in ammonia rapidly dissolves silk and cotton, linen more slowly, but only slightly swells wool.

Cloths are often sophisticated in the process of manufacture, and their value greatly lessened thereby. Wool is mixed with "shoddy," which is made from old and used woollen rags torn asunder and then respun with an addition of fresh wool; silk is heavily weighted with salts of tin, iron, or with other substances; and cotton and linen are stiffened and glossed with an excessive amount of starch, white earth or the like. Shoddy can be determined by the use of the microscope; the weighting of silk by chemical reactions and solutions; and overstarching, etc., of cotton and linen by washing and drying.

It will not be advisable here to go fully into consideration of the influence which the shape and style of the individual garments of ordinary use have upon health, for that would require a much longer discussion than the present space permits; but the general rule may be laid down that each article of clothing should be adapted to the peculiar needs and occupation of the wearer, and that it should in nowise interfere with the proper development, use, or physiological functions of any part of the body.

Trite and hackneyed as is the subject, the writer feels that he would be wanting in the performance of his duty if he failed to condemn the habits and fashions of dress that demand undue constriction of the trunk of the body. All sanitarians practically agree upon the importance of "vital capacity," as measured by the development and extent of expansion of the thorax, in determining the constitution and health of the individual. But not only does the corset harm by interfering with the functions of respiration and circulation, but it also deforms and induces even more serious troubles by its displacement of the abdominal and especially of the pelvic organs, and by the grave interference with the nutrition, tone, and functions of all of these. It is a fair challenge to any woman who declares that she does not dress too tightly, to ask her to measure honestly her waist circumference and expansion both with and without the garment in question, and to make her decision accordingly. And it is certainly false doctrine to teach, as is so often done to young girls, that it is really necessary that the normal human body should have artificial support. The natural muscles kept in proper training, tone, and action are all-sufficient to give the most perfect and most beautiful human form.

When exposed to the sun's rays or to other sources of radiant and incandescent heat, fabrics absorb heat irrespective of the constituent materials, but in the following order as regards color: white, light yellow, dark yellow, light green, Turkey red, dark green, light blue, and black, the latter color absorbing more than and light blue almost twice as much as white, the material in each case being the same. In the shade the degree of absorption depends more on the material than on the color.

Lastly, it should be remembered that, as disease germs are readily conveyed from place to place and from one person to another by the clothing, and especially by that which is hygroscopic by nature, care should be taken to keep the garments in as cleanly and aseptic condition as possible, to disinfect them whenever they have been exposed to infection, and, for those who are much among the sick or liable to infection, the use of smooth, closely woven, non-hygroscopic over or outer garments that can be readily cleansed, such as those made of cotton or linen, is to be highly recommended.

## Light.

The important influence of sunlight in the development the maintenance of a healthful condition in all higher organisms, both animal and vegetable, is well known by every one, but as yet there is a lack of information as to the exact physiological methods and processes which are due to this great force. We know that, for the plants, chlorophyll is the intermediary agent which largely assists in the conversion of carbon dioxide and the storage of carbon in various compounds, and that the presence and action of this chlorophyll are largely dependent upon the light-supply; while for the animal kingdom, and especially for the human race, it is evident that the effect of sunlight is manifested more or less directly in the blood and skin, though the whole body quickly shows a marked appreciation of its presence or absence. But when this has been said, there is little else that can be added as a matter of positive information. No one knows just how the pallid and anæmic child that has been reared in the shade and dark is converted into the tanned and ruddy picture of health in so short a time, but the results are unquestionable.

The subject demands further study, and it may not be out of place to indicate one or two directions in which the investigation may, perchance, be wisely pursued.

In the first place, there has doubtless been too little appreciation of the fact that sunlight in its totality has many other rays of force than those which manifest themselves alone to our sense of sight. The existence of the ultra-violet rays and the fact that these are more powerful actinically than those of the ordinary spectrum have been satisfactorily demonstrated, and the only question is as to what the true physiologic power and influence of these invisible rays may be. It is not certain at present that some of them at least are not closely related to the manifestation of force discovered by Röntgen, and there is good reason to believe that the penetrative powers of light as regards the human body are not fully known or appreciated.[1] Nor can we tell how much of that power of the sun whose effects we feel and see is in nature on that borderland between light and electricity that is as yet so vague and unknown.

Again, the destructive effect of sunlight, and of light from minor sources as well, upon the germs of disease and other low forms of life, and upon their toxic products, is now a matter of common knowledge, though many are not aware that it has been proved that this germicidal action of light is directly in relation to its actinic power. Considering this, together with the statements in the preceding paragraph, may we not surmise that hostile organisms, even in the deeper tissues, are overcome both in this way and by the improved condition of the blood due to the light, and that this hypothesis helps to explain the good results that follow the open-air treatment of many diseases and abnormal conditions? The tubercle bacilli are especially susceptible to its influence, and every one should know that an abundance of sunlight is just as essential to the tuberculous patient as are plenty of good food, pure air, or proper clothing.

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[1] Some experiments by the author and by numerous others seem clearly to indicate that some of the radiant energy from the sun, and in lesser degree from other sources of light, is able to penetrate substances hitherto considered opaque, and to produce phenomena similar to those due to the Röntgen ray. Consequently, if the experiments referred to are well founded, the penetrative ability of this energy, as regards the human tissues, would seem to be more than probable.

Bie[1] has described a treatment by means of light, and has reported some interesting results and apparent cures, in cases of lupus of the skin and circumscribed baldness (alopecia areata). He states that the power of the chemic rays to kill bacteria, to produce an erythema or inflammation of the skin, and to penetrate the skin is already proved. But the strongest light of summer, unconcentrated, is too weak to produce marked results quickly in disease, and as the chemic and bactericidal power of light is mainly in the blue, violet, and ultra-violet rays, measures are taken to concentrate and intensify these by means of a plano-convex lens filled with a solution of copper-ammonium sulphate. This also cools the rays, which would otherwise be intolerable, and further cooling is secured by a smaller hollow plano-convex lens of quartz, through which water is made to flow and which is applied to the part of the skin under treatment and on which the concentrated rays impinge. That the treatment promises much for the future seems undoubted. Finsen has also done much to develop the treatment of disease by sunlight, and his methods are being employed in this country as well as abroad.

More might also be said in reference to the possible and probable chemic activity of the light in and upon the metabolic processes of the animal body; but as there is still the uncertainty of hypothesis and theory, it may be wiser simply to leave the foregoing suggestions as food for thought and incentives to further research and investigation.

The importance of an abundance of daylight in all rooms where much work is to be done should not be overlooked. Not only is it necessary for the conservation of the influences just mentioned, and as a destroyer of pathogenic organisms, but it is also more agreeable and safer for the eyesight than any form of artificial light yet devised. An important aid to the illumination of dark interiors has been the recent introduction of panes or plates of glass with a series of ridges or prisms, which refract and diffuse throughout a room light which would otherwise illuminate it but partially or not at all. The prisms are made with various angles, and may be placed either in the ordinary window sash or in projecting canopies, according to whether the direct light from the sky is obstructed or not. (Figs. 47 and 48.)

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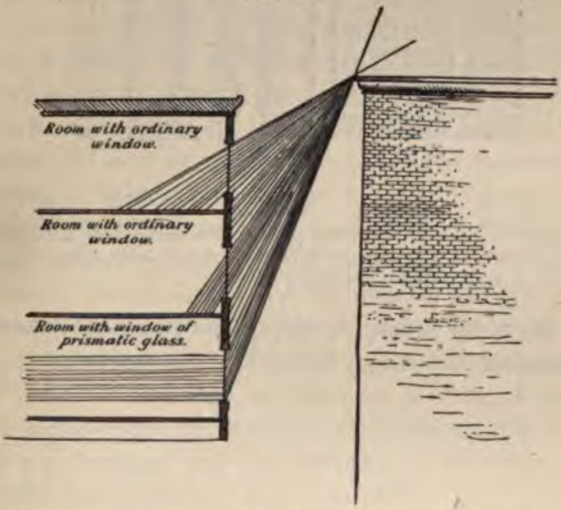
[1] British Medical Journal, September 30, 1899. Philadelphia Medical Journal, October 7, 1899.

FIG. 47.


Room with ordinary window.
Room with ordinary window.
Room with window of prismatic glass.

Action of prismatic glass in projecting light. (HARRINGTON.)

The relation of artificial lighting to ventilation has been discussed. In addition to this point, the quantity of light supplied and its steadiness have an important bearing on the hygienic value of any artificial source of illumination that it may be necessary to employ.

FIG. 48.

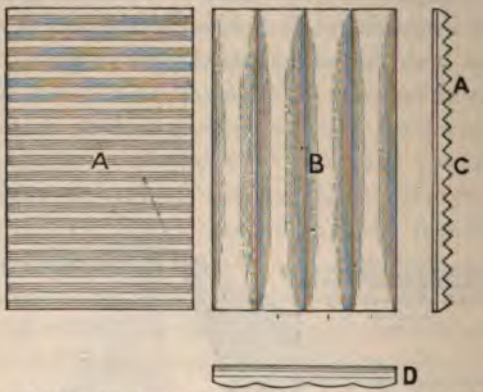


Diagram of American three-way-prisms for refracting and diffusing daylight: A, inner prismatic surface; D, outer refracting lens surface; C, profile or section of A; D, profile or section of B.

# CHAPTER IX.

## SCHOOL HYGIENE.

It was remarked in the chapter on Personal Hygiene that the best time for applying the laws of hygiene is in the days of childhood and youth, for then the whole organism is plastic and yields readily to both external and internal impressions and forces.

This being so, the great influence of the factors common to school life may be readily conceived, and inasmuch as the average child will be subject to them for a large part of from eight to ten or more years, the importance of a study of school hygiene will not be denied. It concerns the parent, the physician, and the citizen, and its investigations must consider the personal hygiene of the scholar, the conditions of his health, his habits, the amount of work done, the sanitary environment and requirements of the school-room and building, the furniture, the ventilation and heating, and the influence of all these upon the individual's state and development.

Next to the scholar himself and his parents, these matters are of special interest to the physician, for, beside being one who from his special training and education is often called to act upon school committees and boards of education, he has to treat many disturbances of health in the young which have their origin or cause in the harmful or insanitary conditions of school life.

There are disorders to which all children are subject whether in school or out; but a special class are markedly influenced by school life or work, and to these abnormal conditions we may give the term "School Pathology." Of some of these, overwork is the cause; others are set up by other factors.

Overwork, coupled with depressed vitality, may give rise in children to one or more of the following troubles: dyspepsia, headaches, nervous derangements, chorea, epilepsy, neurasthenia, backaches, menstrual disorders, and, in some cases, consumption. On the other hand, faulty arrangement of seats and desks, improper location of windows, blackboards, etc., may cause spinal and other physical deformities, defective eyesight, etc. Of the first class, even where the amount of work may not seem or may not really be too much for the capacity of the child, worry about rank or over an approaching examination may have a harmful effect upon a nervous temperament. This is especially so if the examinations come at the end of a spring term, when the scholars are all more or less worn-out and debilitated. The forcing process should be avoided as far as possible, and if grades are to be given at all, they should be as much as possible for the work and attendance during the term, and not so much for the actual work done at examination time.

Moreover, young children should not be kept in school for too many hours in the day, nor should school be looked upon by parents as a place to which to send children to keep them out of the way and from mischief. Edwin Chadwick has shown that a child from five to seven years can only attend to one object for about fifteen minutes; one from seven to ten, for twenty minutes; from ten to twelve, for twenty-five minutes, etc., and that the length of individual lessons and likewise the total day's work should be arranged accordingly. The very early years of school life should be given to inculcating correct habits of attention and of morals and to training the will and powers of concentration and observation, rather than to the teaching of any special knowledge.

But it is probably the work attempted outside after school hours, and not the actual work done in the school, that is most responsible for the breaking down of health, especially in older scholars. In Cleveland, in 1881, of 186 girls in the high school, 29 per cent. of those who studied less than two hours, 70 per cent. of those studying from two to four hours, 93 per cent. of those studying from four to six hours, and 100 per cent. of those studying over six hours daily out of school, had poorer health while at school. Of these same girls, the percentages of those whose health was "very poor while at school," dividing them the same way as regards over-work, were respectively 14, 40, 66, and 100 per cent. This loss of health was attributed by the parents to stair-climbing, irregularity of meals, worry about rank and examinations, etc.; but Goodell says: "So commonly do I find ill health associated with brilliant scholarship, that one of the first questions I put to a young lady seeking my advice is, 'Did you stand high at school?'" Another writer says: "The effects of anxiety are worse than carrying heavy loads."

In fact, one of the leading educators of the country has suggested that children should not be required to study reading, writing, or drawing before the age of ten or eleven, as these bring into action and use the close application of the finer sense organs and faculties which are not as yet fully developed; but he advises that the instruction of the earlier years of school life should consist mainly of language lessons, history, nature studies, and such others as may be taught orally, and that will at the same time develop the child's powers of attention, observation, and reasoning. There is more than a chance that such a plan of instruction would not only secure better results from the teacher's point of view, but that it would also be safer for the scholar's physical organism.

While a child is at school its mind should not be wearied by outside tasks, as music or painting lessons, nor the body weakened by social dissipations, late hours, and indigestible food. Girls are more susceptible to disturbances, and are more subject to them, because they are more willing to undertake extra or double work than boys, and because they are more ambitious and worry more about rank. In all children the obtaining of good health and a sound constitution is of the first importance. Youth is the time for gaining health, not for losing it; for building up sound bodies and constitutions, not for breaking them down, and school life should always have the former as one of its greatest ends. Of what use is all the learning one may gain before the age of eighteen, if there be no strength to use it afterward in the battle of life?

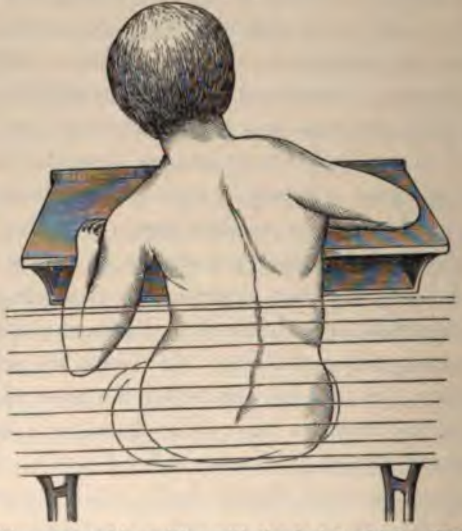
School life is sometimes responsible for dyspepsia by interfering with the regularity of meals, the children missing the midday meal and having to depend upon a meagre lunch, often of sweets and indigestible food. This is especially important when the rest of the family dine at noon, and there is only a light meal served in the evening. Again, many habitually lose their breakfast through fear of being late, or else bolt the food without masticating it and gulp down hot coffee or tea before starting on a run for school. But often the loss of appetite is due simply to lack of fresh air and proper exercise, or else to the nervous condition of the child, which is sometimes such as to interfere with almost all of the body functions. Such dyspepsias are to be treated by attention to the foregoing points rather than by medicine.

Headache is a common disturbance among school children, and may be due to any one of several causes, among which are overwork—producing irritability and disturbances of cerebral circulation—indigestion, bad air, eye-strain, etc. The eyes should always be examined when headaches are persistent, and any defects corrected by proper glasses. Associated with the headaches, frequent bleeding from the nose may occur and should not be overlooked, as it may indicate circulatory disturbance.

One of the most common symptoms of nervous derangement is sleeplessness or restless sleep, and this condition should give warning that something is wrong. Folsom says: "I doubt whether there is an exaggerated prevalence of manifest or well-marked diseases of the nervous system among school children. If due to the school-drill, my impression is that they come for the most part later in life, after the children have left school, and because of constitutions weakened during school years, instead of strengthened as they should be." Children subject to chorea or epilepsy should not attend school, not only for their own sake, but also for that of the other children, who may be unduly affected by their nervous manifestations. Such children should be educated quietly and cautiously, with proper treatment and plenty of out-door life. Neurasthenia or general break-down may occur, usually from overwork, and especially among young women. It may come on unexpectedly after the examinations at the end of the term, when the strain and excitement are removed.

Menstrual disorders are also apt to occur among girls that are being overworked mentally, and we ought to remember that the system is undergoing a heavy strain at the time this function is developing. Also, for certain young women rest from customary work is necessary at the time of the periodical recurrence, and excuses for absence at this time ought to be freely granted. It has been well said that "girls get through as much work as boys, working in their own way."

FIG. 49.

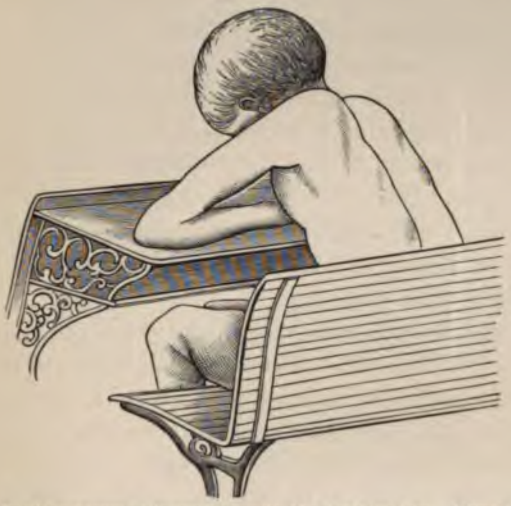


Position assumed in writing with the desk too high. (PYLE.)

The development of consumption may be due to the school life, though it is hard to say how frequently this is the case. Bad air and overwork are both important factors in its production, and if these are forced on underfed or predisposed children the disease may be provoked. "In a consumptive family the steadfast rule should be that the mind be wholly subservient to the body's welfare."

The main cause of spinal and other deformities and defective eyesight is apt to be found in faulty construction of seats and desks, improper location of windows, etc., though excessive work or strain may maintain a low vitality and act as a predisposing condition. The latter point is shown by the fact that spinal curvatures are more prevalent in those especially prone to weakness of the muscles, as women and girls. But no desk or seat will remove original weakness of muscle as the one important predisposing condition, and children cannot be made strong by supports. "Spinal curvature is not only a product of low vitality, but does harm by permanently fixing vitality at a low standard."

FIG. 50.



Position assumed in writing with the desk too low. (PYLE.)

Improperly arranged seats and desks not only often cause spinal deformities, but also help to develop defective eyesight by causing the scholar to hold the book too near the eyes and by making him bend his head so that the circulation of blood is impeded and ocular congestion favored. However, no seat can be devised in which a child will maintain a correct or "normal" position for any but a short time, as this is an impossibility for young children; but the aim should be to furnish a seat in which one will naturally assume the correct position after having temporarily taken any other. "Movement is a child's way of resting; rest is a kind of work, to be taught by degrees." Seats should have backs to prevent fatigue, but a comfortable back gives support to the lower part of the spine rather than to the shoulders and upper part of the spine. Many foreign authorities advise seats with backs only high enough to support the lower part of the spine, and low enough for the scholar to rest his elbows upon them while studying.

The following points, suggested by Lincoln, are worth noting: "1. The chair is often too high for young scholars. The most convenient plan may be to provide footstools. 2. The seat from back to front ought to be long enough to support the whole thigh. A more or less spoon-shaped hollow in the seat is commonly thought desirable. The curve of many settees is such as to produce pain at the point where the tuberosities of the ischium rest on the wood; the support is there not wide enough. 3. Seats must have backs. The straight, upright back reaching to the shoulders is bad; a straight back, slightly tilted, is not bad. American seats are commonly curved, with curved backs. 4. The edge of the desk should come up to or overlap the edge of the seat. The recognition of this fact is a recent discovery. 5. Most of our best desks are too high relatively to the seat, doubtless to prevent the pupil from stooping. Something is gained in convenience of reading by this plan, but it interferes with correct positions in writing. The elbows, hanging freely, should be only just below the level of the lid." For near-sighted children the higher desk may be a necessity in writing; if the desk is made low, a portable writing-stand may be placed on top of it when necessary.

Windows on only one side of a large school-room may not give sufficient light for the desks most remote from them. Consequently there should be windows on two sides, preferably adjoining ones, of large school-rooms. The windows should be at the back and to the left of the scholar, thus giving the best light upon the desk for either reading or writing. They should not be placed in front of the scholars, as the continuous glare is very trying and injurious to the eyes. They should extend almost to the ceiling and have square tops, to admit as much light as possible. Blackboards should have a dead-black surface, not a glossy one, and should be on the sides of the room on which there are no windows. Walls should be of a neutral tint, not glaringly white.

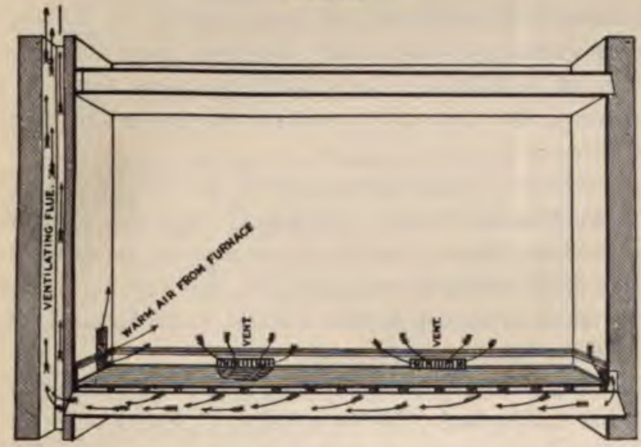
**Construction of School-houses.**—The principles already given as to ventilation, heating, water-supply, etc., apply here as elsewhere. From 1800 to 2500 cubic feet of fresh air should be supplied to each scholar per hour. In cold weather this should, of course, be satisfactorily warmed. The air-ducts, both inlets and outlets, must be sufficiently large to change the air without causing injurious and uncomfortable draughts; and these ducts should be as short and free from bends as possible, or, better, the rooms should open into the supply and exhaust shafts directly. The air may be warmed either by steam or hot-water coils or by a furnace, though preferably by the former, to avoid "baking" the air, and also preferably by the indirect system. There is no objection to having additional heating apparatus in the school-room, provided it is guarded so that the scholars may not be accidentally burned. Any system that will give a sufficient supply of fresh air properly heated will of necessity be more expensive than the old way of not ventilating at all except by opening the windows at recess time, but experience shows that the increase in expense is not so very great, as so much heat is lost by opening the windows in this way, and the benefit to the children more than compensates for the additional outlay. Country schools may be heated by stoves surrounded by sheet-iron drums, and ventilated with fresh air from without brought in near the bottom of the stove. (See Fig. 20.) Passing up between the stove and drum the air is warmed and gives good ventilation without chilling or draught. As great a length as possible of stovepipe should be exposed in order to get the full benefit of the heat from it.

The Smead system of ventilation and heating has been used with satisfaction in many schools throughout the country. In this, the air after being warmed and brought into the school-rooms at a level a few feet above the floor, circulates through them and is finally withdrawn through registers at the floor level, whence it is carried underneath the floors to large outlet shafts in which a draught is constantly maintained. In this way a thorough diffusion and changing of the air in the school-rooms are secured, and, moreover, the floors are kept warm by the heat from the air which is passing beneath them but which would otherwise be wasted. (Fig. 51.)

Ample cloak-rooms should be provided for every school, which should be warm and well ventilated in order to secure the rapid drying of the garments in wet weather, but these cloak-rooms should not, if it is possible, communicate directly with the school-rooms themselves. Provision should also be made for readily disinfecting them, and, in fact, the whole school building at intervals and whenever necessary.

In 1897 at Newcastle-upon-Tyne, "the experiment was tried of closing each school, where scholars were being taken ill, for a few hours only, long enough to allow of thorough purification and the *sprinkling of the floors of class-rooms with disinfectants.* This disinfection, so far as measles was concerned, was followed by the extinction of the disease in question."[1]

FIG. 51.



Illustrating the Smead system of ventilation.

The school-house should be on dry and well-drained soil, as dampness is not only depressing to all constitutions, but is also an important factor in the causation of phthisis and strumous diseases. There should not be too much shade about, and as many rooms as possible should have sunny exposures. If the sunlight is annoying during the session, it may be excluded by inside blinds or shutters, but we must not lose sight of its helpful influence in the destruction of bacteria and purification of organic matters.

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[1] American Year-book of Medicine for 1900, pp. 543, 544.

Where sunlight is scanty or it is difficult to illuminate the school-rooms, it may be advantageous to furnish one or more of the windows with some form of the diffusing and refracting prisms already described (page 298), thus giving an abundance of light where there was formerly a deficiency, and materially lessening the eye-strain of the scholars.

Basements of school-houses should be well lighted and dry, and should be kept scrupulously clean that moisture and noxious gases may not be drawn into the rooms above. If properly arranged and cared for, they may be used as play-rooms in stormy weather when it would be unwise to send the scholars out-of-doors.

The water-supply should be free from impurities and as good as can be had. In the country, if from a neighboring farm-house spring or well, it may be contaminated by eakage from cesspools and barnyards. Or the school water may be taken from a neighboring spring or stream which is receiving contamination from the school-house cesspool or other sources. For this reason, teachers should be taught the tests for chlorides and ammonia and the reason for making them, and should make these tests frequently. If cause for suspicion arises, the use of the water should be stopped at once.

Water-closets and urinals, where in use, should be kept clean by a competent janitor, and the principal or head-teacher should see that this is done. In the country, the pail or earth-closet system should be substituted for the usual privy-vault or cesspool, and it should be the duty of some one apart from the teacher, regularly appointed and paid by the school directors of the district, to see that removals are made at proper intervals; the teacher should maintain supervision over the daily condition of affairs. If possible, the out-houses should be connected with the school-house by covered ways, that the children may not be exposed in inclement weather; but these ways should be open or else constantly ventilated by open windows on either side. Cesspools, if unavoidable, should be at least fifty feet distant, and should drain away from the school-house.

Though approving the Smead system of warming and ventilation for school-rooms, the writer cannot say that he approves that modification of it wherein the foul air from the building is carried over the fecal excreta of the inmates before being discharged into the outlet shafts and carried to the outer air. Though the method rapidly desiccates the excreta and renders it inoffensive to the senses, there is danger of the dissemination of disease germs as well as a departure from sanitary principles in the method.

Ample provision must be made for the rapid escape and for the safety of scholars and teachers in case of fire or panic. Fire-drills should be regularly practised in all schools of two stories or more, and presence of mind inculcated, that emergencies may be met with safety. The comfort of the child should not be forgotten in the construction of the school-house, though preservation of health is the main aim.

**School Quarantine.**—As certain diseases are contagious, it is necessary that school authorities have the right to forbid the attendance of such persons as have been exposed to infection until all danger of transmitting the disease to others is passed. This power is usually, however, exerted only in the case of those diseases most dangerous to life and health, though the stringency of the regulations varies at different places. Smallpox, scarlet fever, diphtheria, measles, and even whooping-cough should always be quarantined, and it would be better to keep children who are afflicted with minor diseases of this class out of school till all danger of infection is over, as it is only by rigid measures like this that we may finally be able to eradicate those maladies. Considerable evidence now supports the view that there is a marked decrease in the prevalence of both scarlet fever and diphtheria during the summer holidays and an increase due to school attendance. But Niven, of Manchester, England, thinks that "the extreme measure of closing a school for scarlet fever is rarely called for, and is not so likely to be effectual as in the case of measles."[1]

Local boards of health should make and enforce rules looking to the prevention of the spread of the graver contagious diseases, and should, when necessary, close school-buildings till all danger is past. Lincoln gives the following as a system of general regulations: "1. Persons affected with diphtheria, measles, scarlet fever, or smallpox (varioloid) must be excluded from the schools until official permission is given by the board of health for their readmission. 2. Persons living in a family or house where such a case occurs are also excluded until similar permission is given. 3. This permission is not to be given until sufficient time has elapsed since the occurrence of the last case to insure safety, nor until the premises have been disinfected under the direction of the board of health. 4. If a child suffering from one of the above diseases attends school, the premises of the school must be disinfected under the direction of the board of health before they are used again. 5. Physicians, teachers, school officers, and school children knowing of such cases of disease should at once report them to the board of health. 6. The board should also notify the school authorities of all such cases. 7. Notice must be sent to the family by the school authorities, acting conjointly with the board of health."

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[1] See Public Health, February, June, and September, 1899; also, American Year-book of Medicine for 1900, p. 538.

The following table of the periods of incubation of the respective diseases is based on an experience of over twenty-eight years at the Rugby School, England, by Clement Dukes.[1]

An Analysis of the Periods of Incubation.

| Name of disease. | Shortest period of incubation (days). | Longest period of incubation (days). | The largest number occur on the following days. | The majority of the cases arise between the following days. | Percentage referring to previous column, *e. g.*, 59 per ct. occur between the second and fourth days. |
|---|---|---|---|---|---|
| Scarlet fever . | 1 | 9 | Second and fourth | Second and fourth | 10 out of 17 = 59 per cent. |
| Chickenpox . . | 13 | 19 | Fifteenth | Fourteenth and seventeenth | 24 out of 36 = 66 per cent. |
| Mumps . . . . | 14 | 25 | Nineteenth | Seventeenth and twentieth | 50 ont of 69 = 72.46 per ct. |
| Rose-rash . . . | 12 | 22 | Sixteenth | Fourteenth and seventeenth | 31 out of 40 = 77.50 per ct. |
| Measles . . . . | 8 | 14 | Eleventh | Ninth and twelfth | 18 out of 24 = 75 per cent. |

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[1] Lancet, April 29, 1899.

Another authority gives the following:

TABLE OF THE ERUPTIVE FEVERS.

| Name. | Incubation. | Day of rash. | Duration of eruption. | Duration of disease. |
|---|---|---|---|---|
| Chickenpox . . . | 4 to 14 days | Second or third | 4 to 8 days | 1 to 2 weeks |
| Erysipelas . . . . | 1 to 5 days | First to third | 4 to 8 days | 1 to 3 weeks |
| Measles . . . . . | 10 to 12 days | Fourth | 3 to 5 days | 10 to 14 days |
| Rötheln . . . . . | 7 to 17 days | First or second | 1 to 3 days | 4 to 7 days |
| Scarlatina[1]. . . . | 1 to 21 days | Second | 4 to 10 days | 2 to 3 weeks |
| Smallpox. . . . . | 8 to 14 days | Third or fourth | 16 to 25 days | 3 to 5 weeks |
| Typhoid fever . . | 10 to 21 days | Seventh to fourteenth |  | 3 to 4 weeks |

Children having had one of the above-named diseases may return to school with safety after the following periods, provided there has been a thorough disinfection of their homes and clothing: "Scarlet fever, six weeks from the date of rash, provided desquamation and cough have ceased. Smallpox and chickenpox, when every scab has fallen. Whooping-cough, after six weeks from commencement of whooping, provided the characteristic spasmodic cough and whooping have ceased, or earlier if all cough have passed away. Diphtheria, not less than three weeks, if convalescence is completed; there being no longer any form of sore throat nor any kind of discharge from the throat, nose, eyes, ears, etc., nor any albuminuria." Wherever possible, a bacteriological examination of the nose and throat secretions of a scholar that has had diphtheria should be made from time to time, and his return to school should only be permitted when this examination no longer shows the presence of the specific organism in the secretions mentioned. Rules and regulations like the above, when promulgated, "should have the force and authority of law, and should be enforced, if necessary, by the entire power, including school officers, etc., of the State."

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[1] In regard to the discrepancy in the above tables respecting the incubation of scarlet fever (from one to twenty-one days) the writer believes the shorter period to be more nearly correct; also that the incubation period of measles is frequently less than ten days, as is occasionally that of typhoid fever. Relapses may extend the duration of typhoid fever to much more than four weeks.

Boarding-schools and similar institutions should have an infirmary where contagious diseases may be isolated, and those in charge should make that isolation from other scholars and inmates as complete as possible. At the beginning of a term it may be well to subject scholars who have been exposed to contagion to a postponement of attendance until the probable period of incubation for the special disease is passed, the period dating from the time of exposure. With the above precautions it will rarely be necessary to close a school unless a disease is markedly epidemic and malignant.

It is to be hoped that we shall soon have a means of inoculating persons against all contagious diseases, as we now do against smallpox. At present, boards of health and school boards should insist on the vaccination of all school children. In Illinois, from 1880 to 1883, the deaths from smallpox among unvaccinated children were 48 per cent. of those incurring the disease; among the vaccinated, only 0.9 per cent. In Philadelphia all who desire it are vaccinated free of charge by the vaccine physicians, and it is compulsory for all school children.

Lincoln has also suggested that further regulations similar to the following should be in force in every school district: "Every child entering the public schools must show a certificate from some reputable physician, giving name, age, residence, approximate date of vaccination, date of examination, result of examination, the last two to be of the physician's own knowledge. The fact of vaccination must be entered on the school record and on lists for promotion and transfer. The school authorities shall annually report the number of those not protected to the State Superintendent of Education. School authorities may order the exclusion of non-protected persons, after sufficient notice, where they think the measure required for the public health. Re-vaccination at the age of fifteen may be required under similar circumstances. Those unable to pay should be furnished with free vaccination by the school authorities. A physician's certificate of protection by a previous attack of smallpox is equivalent to a certificate of vaccination."

Contagious ophthalmia is a disease often prevalent in charitable and educational institutions and occasionally in primary schools, and requires great care to prevent its invasion and spreading, as well as to effect a cure. Those afflicted with it should be quarantined until there is no further discharge or till the granulations on the inner surface of the eyelids have disappeared. Enfeebled health and poor and insufficient food favor its development, but the chief means of contagion is by the use of the same wash-basins and towels by a number of children.

Other diseases that may be transmitted in much the same way are chronic conjunctivitis ("granular lids") and those due to fungous and other parasites, as the tineas ("ringworm of the scalp or face"), pediculosis, etc., all of which may be transmitted by an interchange of hats or caps or other garments.

School children should not be allowed to attend the funerals of companions dead of a contagious disease, nor should funerals be allowed to take place from schoolhouses under any circumstance, owing to the effect on the thoughts and sensibilities of nervous children.

# CHAPTER X.

## DISINFECTION.

As has been stated, disinfection is that part of prophylaxis which has to do with the destruction or modification of the exciting causes of disease, and we may accordingly define a *disinfectant* as "an agent capable of destroying the infective power of infectious material," or, as "an agent which brings about the destruction of bacteria in general, and more particularly of those that act as the exciting causes of disease."[1] Consequently, as with our present knowledge we are practically limited in the use of disinfection to the infectious diseases only, a disinfectant must also be a *germicide*. Theoretically, it should also have the power of destroying the poisonous properties of the toxins which the disease germs produce, and which create the characteristic symptoms of the specific diseases; but whether all efficient disinfectants have this power is by no means proved; nor is it altogether essential that they do have it, since by killing the germs we check the further production of the toxins; and disinfectants are mainly used not so much to cure or arrest the progress of a disease in a patient as to prevent its incurrence by others. But, in a popular sense, the term disinfection is given a wider meaning than is indicated above, including not only the use of antiseptics and deodorants, but also often the actual removal of filth and all matters favorable to the growth or spread of disease germs, which is, strictly speaking, a matter of sanitation. It is needless to say that the latter work may be part of the prescribed duties of a disinfector, but it is not one of the essential functions of a disinfectant.

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[1] Harrington, Practical Hygiene, p. 488.

It will be well here to make the distinction between disinfectants and antiseptics and deodorants, as the terms are often wrongly used interchangeably, and there is a common belief that whatever is a deodorant or an antiseptic is also a disinfectant. An *antiseptic* is an agent that retards or arrests bacterial growth and the consequent production of toxins or ptomaïns, though it does not necessarily kill the micro-organisms themselves; and though some antiseptics are germicidal, others are not, and therefore as a class they cannot be considered or used as disinfectants. But, on the other hand, "agents which kill bacteria in a certain amount prevent the multiplication of the latter in culture-fluids when present in quantities considerably less than are required to destroy vitality." So, a diluted germicide may act as an antiseptic and may be used therefor. For instance, chlorinated lime, which is a good disinfectant in solutions of proper strength, may arrest further bacterial growth or action in a mass of sewage or filth and prevent the latter acting as a culture-medium for disease germs, even though the agent be totally inadequate in quantity to kill all the micro-organisms present. In the same way, it may act as a *deodorant*—which, by the way, is an agent that simply removes or destroys offensive odors, and is not necessarily either a disinfectant or an antiseptic—both by checking the further action of saprophytic bacteria and the consequent formation of putrefactive odors, and by actually decomposing and oxidizing those of the latter lready formed.

In practical disinfection it is also well to remember that while masses of dead organic matter may not in some cases contain disease germs, and may be even hostile to them, in general the reverse of this is more likely to be true, and decaying matter often furnishes a good field for the increase of pathogenic organisms. Moreover, the noxious gases given off to the air and the poisonous products added to a drinking-water from such masses may also do much harm by depressing the system, lowering the vitality, and acting as predisposing conditions to the incurrence of such filth diseases as cholera, yellow fever, typhoid and typhus fever, diphtheria, etc.; and when time or opportunity does not permit of the removal of such dangerous accumulations, their power for harm should be checked permanently or, at least, temporarily by the use of suitable disinfectants or antiseptics.

But when we are actually dealing with disease germs, disinfection, to be trustworthy, must be carried out to the best of our ability with the means at our command and with strict attention to the minutest details. "There can be no partial disinfection of infectious material; either its infectious power is destroyed or it is not. In the latter case there is a failure to disinfect." This is because the undestroyed living bacteria still have the power of reproduction, and may, within a very short time under favorable circumstances, equal or even exceed the number that was present before the unsuccessful attempt at disinfection was made. In fact, our aim in such prophylaxis must always be "to interrupt all possible paths of disease conveyance, and to exterminate the causal agent."

The knowledge as to the efficacy of any substance as a disinfectant is obtained from the accumulated experiences of practical sanitarians and from experiments on susceptible animals and in culture-media in which infectious matter is treated with the substance in question or that is being tested. The knowledge gained must stand the test of scientific deduction, and a substance is not a disinfectant simply because, in one given case, infection did not occur after its use. To be of value the deductions must be made from considerable accumulated and practical experience. "Negative evidence should be received with great caution;" but if the experience of practical sanitarians is confirmed by careful culture and inoculation experiments, our knowledge of the value of any agent becomes more definite and our practical work more exact. From such inoculations and experiments it has been found that the infectious germs of different diseases differ in their power to resist the different disinfectants; but nevertheless it may be stated that "in the absence of spores, a disinfectant for one is a disinfectant for all." Consequently, we are able to simplify and classify the agents at our disposal and to make more effectual use of them. Note that there is nothing in the tests mentioned that tends to disprove the efficacy of disinfectants, whatever the nature of the infecting material and whether the germ theory be accepted or not.

Some agents that are powerful against all other organisms completely fail to destroy the vitality of spores, and thus our list of disinfectants available in *all* cases is still further reduced. In the case of a disease germ that does not produce spores, as that of cholera, and probably also of scarlet fever, smallpox, yellow fever, etc., agents may be used that are powerless against spores, but in doubtful cases only those should be used that have the power of spore destruction.

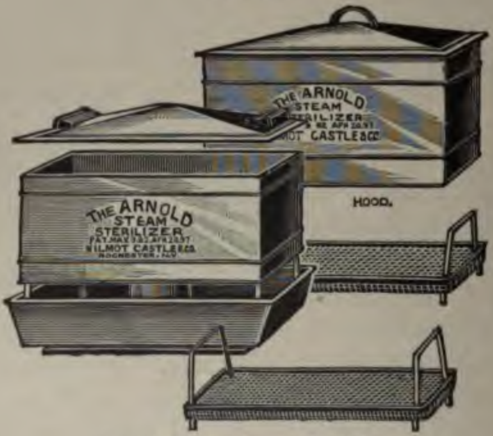
We may classify the disinfectants of which we may make practical use as either *thermal* or *chemical*, though there are undoubtedly certain secretions and tissues in the body which have the power of destroying infective matters, giving each person more or less immunity against certain diseases, and these we may term *physiological* disinfectants.

There may also be a *mechanical* sterilization, as in the separation of micro-organisms from a liquid by filtration or sedimentation, or by their physical removal from very smooth articles by wiping, or from the human skin by thorough scrubbing and washing. Whether the latter may prove efficient depends on the smoothness of the person's skin, his exposure to pathogenic germs, and especially upon the care and thoroughness with which the cleansing process is accomplished.

**Thermal Disinfectants.**—Of the thermal disinfectants, *fire* is the most efficacious, as it destroys all organic matter, but it can only be used to disinfect non-combustible articles or those that are of little value and that cannot be safely disinfected in any other way. For instance, as it will usually cost more than they are worth to disinfect thoroughly by other methods old mattresses that have been used in an infectious case, it is best to burn them.

All things considered, *steam* is probably the most practically efficient disinfectant, as it is cheap, easily used and manipulated, and is less liable to injure the articles to be disinfected. We employ it under pressure, when its temperature is correspondingly increased, or in the streaming state (live steam), the latter being as efficient as the former, but sometimes requiring a little longer time. For instance, steam at 240° F. is said to kill the most resistant spores very quickly, and streaming steam at 212° F. will produce the same effect within thirty or forty minutes. In fact, under very favorable conditions, probably few, if any, of the ordinary pathogens can withstand the temperature of boiling water (212° F.) longer than a few minutes, but it is always wise to employ sufficient time and heat to remove any possibility of doubt or danger. One should also remember that for surface disinfection streaming saturated steam is relatively much more efficient than superheated steam, on account of the great liberation of latent heat when the former condenses, and possibly because the latter tends to dry rather than moisten the organisms and thus render them harder to disinfect. Special apparatus for disinfecting large articles by steam is now or doubtless soon will be established in every large city and hospital by the municipal authorities and others, as a sanitary precaution and to prevent the spread of epidemics.

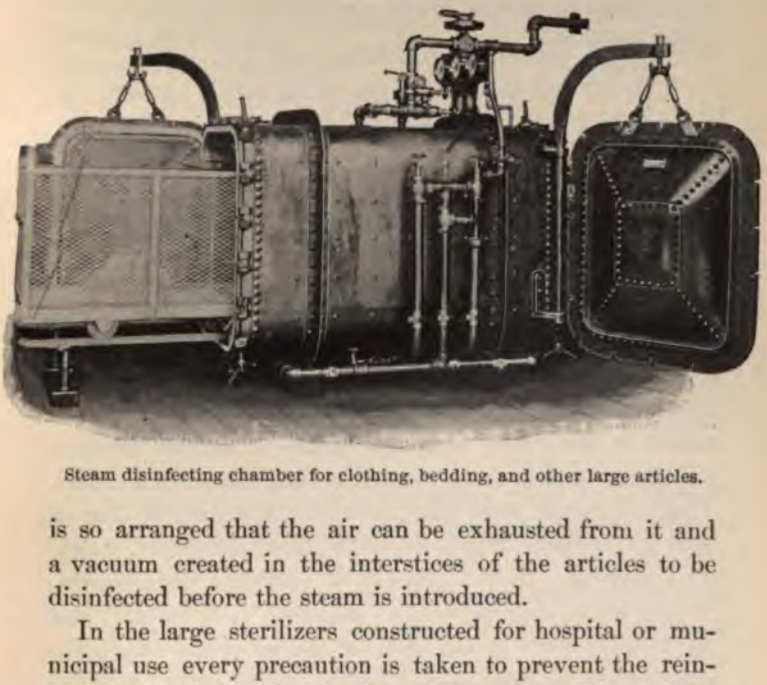
FIG. 52.


THE ARNOLD STEAM STERILIZER
WILMOT CASTLE & CO.
HOOD.
THE ARNOLD STEAM STERILIZER
WILMOT CASTLE & CO.
ROCHESTER, N.Y.

Steam sterilizer for small articles.

In steam sterilization, as with all other disinfectants, the aim must be to bring the germicidal agent into contact with every part of the infected matter; in other words, to secure thorough penetration. The size and compactness of the articles to be sterilized accordingly govern in part the duration of their treatment by the steam. Steam under pressure is, of course, more penetrating than live steam, and is especially expeditious when the apparatus is so arranged that the air can be exhausted from it and a vacuum created in the interstices of the articles to be disinfected before the steam is introduced.

FIG. 53.



**Steam disinfecting chamber for clothing, bedding, and other large articles.**

In the large sterilizers constructed for hospital or municipal use every precaution is taken to prevent the reinfection of articles after they have been once sterilized. The goods enter the apparatus at one end, and after the treatment are taken from it at the other end, being handled and delivered to their owners or destination by an entirely different group of employés and conveyances than those concerned with them before the disinfection. The apparatus is built into a closed partition, which entirely separates the two parts of the disinfecting building and prevents any transmission of germs from the infected to the disinfected side, especially as the doors of the sterilizer are, or should be, so arranged that they cannot both be open at the same time.

BOILING-POINT OF WATER UNDER STEAM-PRESSURE.[1]

| Steam-pressure (pounds). | Boiling temperature. (F.) | (C.) |
|---|---|---|
| 0 | 212° | 100.0° |
| 5 | 228° | 109.0° |
| 10 | 240° | 115.5° |
| 15 | 251° | 121.5° |
| 20 | 260° | 126.5° |
| 40 | 287° | 141.5° |

In the absence of spores, bacteria are killed by *hot water* even below the boiling-point, and it is safe to say that boiling for ten or fifteen minutes will kill all known disease germs, especially if from 1 to 2 per cent. of washing soda or a little common salt (sodium chloride) be added to the water; although spores of certain harmless bacilli are said to have resisted boiling for several hours. The addition of soda also prevents the rusting of iron or steel instruments, but is likely to cause erosion of aluminum articles. In the absence of chemical disinfectants, boiling water may be used to disinfect excreta, etc.; and all clothing worn by the sick or the attendants upon the sick should be well boiled before using again, whether other disinfectants are employed or not.

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[1] McFarland and Babcock, in Cohen's System of Physiologic Therapeutics, vol. v., p. 201.

*Dry heat* is far less penetrating and less effective than moist, and must accordingly be used at much higher temperatures and for a longer time. At 300° F. dry air will require at least three or four times as long to do what steam at 212° or 220° F. will do, and, moreover, it is very apt to injure clothing or other organic materials exposed to it at such high temperatures for so long a time as is necessary. Consequently, it is only to be used to disinfect articles that would be spoiled by moisture or chemicals, and even then it is better to employ the "fractional" method of disinfection—*i. e.*, exposure to high temperatures for short periods only, but for a number of times, with sufficient intervals between the exposures to allow the development of any spores that may possibly be present.

Contrary to the popular opinion, cold is not a positive germicide, or at best is but a slowly acting one. Typhoid germs have been frozen for more than one hundred days without losing their power for harm, and various micro-organisms have withstood the temperature of liquid air—below —300° F.—for several hours or days. However, freezing, especially if intermittent, is harmful to the growth of bacteria, and they gradually decrease in number in frozen material.

In this connection it is not out of place to refer again to the germicidal power of light, especially sunlight, and to its value as an adjunct in the disinfecting of rooms, clothing, etc. It is an agent that may be used progressively and efficiently in the sick-room throughout the course of an infectious disease; and psychically, as well as otherwise, adds to the cheer and comfort of the patient rather than to increase his discomfort, as does the use of most other means to the same end.

**Chemical Disinfectants.**—Regarding the chemical disinfectants, it must be remembered that it requires a certain amount of each to disinfect a given quantity of bacteria, and also that, with all disinfectants, time is an important element, as none act absolutely instantaneously. Heat, however, facilitates and increases the rapidity of action of the chemical disinfectants.

Another caution to be observed is that the disinfectant should always be of sufficient strength in the *mixture* with infected material. For example, if a disinfectant is only effective in 1 per cent. strength or more, then at least a 2 per cent. solution should be added, volume for volume, to the matters to be disinfected, and should be thoroughly mixed with the latter in order that the germicide may be brought into contact with all the infective organisms.

*Chlorinated lime* (often called chloride of lime) is one of the best and cheapest disinfectants. It should contain at least 35 per cent. of available chlorine, should be kept covered from air and moisture, and fresh solutions should always be made as needed. Its power is due to hypochlorite of lime, which is freely soluble in water and readily decomposes in contact with organic matter, giving up chlorine gas—a most powerful disinfectant. "Germs of all kinds, including the most resistant spores, are destroyed by this solution; but it must be remembered that the disinfectant itself is quickly decomposed and destroyed by contact with organic matter, and that if this is present in excess, disinfection may not be accomplished, especially when the germs are embedded in masses of material which are left unacted upon after the hypochlorite of lime has been all exhausted in the solution." Labarraque's solution of *chlorinated soda* is a very mild disinfectant, but does not keep well, and chlorinated lime is equally as good and much cheaper. However, the soda solution has scarcely any disagreeable odor, and makes a pleasant disinfecting bath for the person. The official solution must contain at least 3 per cent. of available chlorine, but it may be diluted with from two to five parts of water before use, especially for bathing.

Though probably effective against sporeless bacteria in somewhat less proportions, solutions of chlorinated lime should be of at least 1 per cent. strength by weight, and should be used in excess, to allow for both the dilution by the mass to be disinfected and the exhaustion of the hypochlorite by organic matter.

*Bichloride of mercury* is one of the best germicides that we have, and is effective in comparatively weak solutions. It corrodes metal, and so cannot be used to disinfect waste-pipes, etc.; and it combines with and coagulates albumin, which interferes somewhat with its action. This coagulation is prevented to a degree by the addition of a small amount of citric or tartaric acid or of ammonium chloride to the disinfecting liquid. The same result is said to be obtained if one part of hydrogen peroxide (fifteen volume solution) be added to three parts of a corrosive sublimate solution of any strength, or by adding common salt (0.5 to 1 per cent.) to the solution. But for the above reason it is better not to use corrosive sublimate in disinfecting fecal excreta or sputum, as these always contain more or less albumin, and also because the sulphur present in the excreta permits the formation of a sulphide of mercury, which has almost no power as a disinfectant. A lime solution is better and more certain.

Bichloride of mercury should be used in solutions of from 1 in 1000 to 1 in 500 strength for ordinary disinfection, though weaker preparations are sometimes used in surgical cases. It is especially valuable where a large amount of fluid is to be freely used, but the solutions should always be colored by a little aniline dye or copper sulphate, on account of its poisonous properties, and the consequent danger from its lack of color. Abbott cautions that the stains of blood and feces on clothing are rendered almost indelible by long soaking in bichloride solutions. Silver nitrate is almost, if not fully, as good a disinfectant as bichloride of mercury, and does not coagulate albumin so readily, but is much more expensive.

*Carbolic acid* is effective in the absence of spores, and, according to Koch, should have first place in disinfection against the cholera germ. It is of doubtful value, however, in cases of typhoid fever, as it is said that the typhoid bacilli can be cultivated in a medium containing 0.5 per cent. of carbolic acid. Solutions should always be made by first dissolving the acid in hot water, and should contain from 2 to 5 per cent. of acid, the latter being practically a saturated solution. The stronger solution is especially valuable for the direct disinfection of human excreta of all kinds, but must be thoroughly mixed with the same, as carbolic acid coagulates albumin somewhat, while the weaker fluid (2 or 3 per cent.) may be used freely for the disinfection of clothing or the washing of walls, floors, furniture, etc.

A 2 or 3 per cent. solution of a mixture of equal parts of carbolic and sulphuric acids is valuable for the disinfection of water-closets, urinals, etc., as the latter acid increases the effectiveness of the mixture; but it must not be kept too long in contact with metals on account of the corrosive action of the sulphuric acid.

Solutions of the *kresols* (meta-, para-, and ortho-), which are derived from coal- or wood-tar, and much resemble carbolic acid, may be used for the same purposes and in about the same strength as solutions of the latter. In fact, *trikresol*, which is a refined combination of the three, is two or three times as powerful a disinfectant as carbolic acid, and, in solutions of from 0.5 to 1 per cent. strength, makes an agreeable and efficient disinfectant for use in surgery and obstetrics, especially as it does not coagulate albumin as readily as do carbolic acid and corrosive sublimate. As carbolic acid and kresol solutions are all poisonous, they should always be so labelled, although the characteristic odor serves as a partial safeguard to those accustomed to it.

The kresols do not corrode metals and can be used with soaps and oils, both of which features increase their usefulness for surgical and other purposes.

*Creolin* is another coal-tar product that has some germicidal power, but is not so efficient as was formerly credited. Being cheap, it may be used freely for disinfecting drains, stables, urinals, and such places where its rather strong odor is not objectionable. It should be made up in from 2 to 5 per cent. strength in water, and, being insoluble, the mixture must be thoroughly stirred or shaken each time before use.

*Zinc chloride* is a good antiseptic and deodorant, but not a very powerful disinfectant. A 5 or 10 per cent. solution will kill germs without spores.

*Calcium hydrate*, when mixed with water to make a thin whitewash (milk of lime), is said to be a good disinfectant, especially for excreta, etc., and is one of the cheapest and easiest to obtain. It should be added to the infectious matter in excess or until the mixture is decidedly alkaline, and will require from one to two hours to disinfect thoroughly.

The proportion of lime to water should be about as 1 to 4, equal parts being first taken to allow the slaking of the lime, and the rest of the water then added and the mass thoroughly mixed by stirring. Two quarts of this mixture per day for each person using a cesspool will keep the contents of the latter disinfected and free from putrefactive odors, provided its use commences with the use of the cesspool, or that the prior contents have been disinfected by an excess of this or a chlorinated lime solution, or by an abundance of the latter salt or quicklime in powder.

*Sulphate of iron*, which acts as an antiseptic to prevent putrefaction, rather than as a disinfectant, may also be added to the contents of an offensive cesspool or one that has received infected matter to the extent of about four pounds for each cubic yard of the mass. The sulphate should, of course, be thoroughly dissolved before using.

An extremely valuable disinfectant for local or topical applications to the person is *hydrogen peroxide* or *dioxide* ($H_2O_2$). It is harmless, even when taken internally; is effective in comparatively weak solutions, and is especially active in the destruction of pus organisms. It is usually supplied in the form of a 15 per cent. solution in water and at present only its high cost prevents its more extended use.

Until the discovery, in 1892, of the great disinfecting power of formaldehyde or formic aldehyde by Trillat and Aronson, about the only gaseous disinfectants of practical value were *chlorine* and *sulphur dioxide*.

Of these, chlorine is the most powerful and efficient, but the distressing and oftentimes serious symptoms which it produces when accidentally inhaled, and the bleaching effect that it has upon many articles, have both tended to prevent its common employment. Like the sulphur dioxide, it acts best in the presence of moisture, and therefore steam should be simultaneously introduced and liberated in the room or enclosure in which either of these disinfectants is used. Sufficient chlorine for 1000 cubic feet of space may be generated by carefully pouring two fluidounces of strong sulphuric acid and three fluidounces of water, previously mixed and cooled, upon eight ounces of sodium chloride (common salt) and two ounces of manganese dioxide. The acid must be added to the water little by little and with care, and the salt and manganese should be in an earthen vessel upon a bed of sand, to prevent injury to the floor or carpet. Moreover, as the chlorine gas is very heavy, the generating apparatus should be at as high a level as possible in the room to get even fair diffusion.

Sulphur dioxide ($SO_2$), though not so positive in its action as chlorine, is more frequently employed on account of the lesser risk and trouble connected with it. It probably kills germs not containing spores if sufficiently concentrated and in the presence of moisture, and is therefore useful in the fumigation of rooms and of articles that cannot be subjected to steam heat or chemical solutions. But it will bleach or tarnish many articles, and for this reason and the fact that it is much inferior to formaldehyde, it will hereafter probably be almost entirely supplanted by the latter whenever that can be obtained.

To secure sufficient concentration at least three pounds of sulphur should be burned for every 1000 cubic feet of air-space.

The sulphur should be well moistened with alcohol, unless the prepared sulphur candles now on the market are used, and allowance should be made for a considerable proportion that is usually not burned. Care must also be had to guard against setting fire to the room from the sputtering of the sulphur, and especially to have present in the atmosphere an abundance of aqueous vapor.

Before the fumigation of a room with chlorine or sulphur dioxide, or with formaldehyde, all apertures and crevices in the walls, ceiling, or floor should be carefully closed from the outside, to maintain the gases in as concentrated a state as possible during the process, which should continue for at least twenty-four hours in the case of chlorine or sulphur gas, and for not less than twelve hours with formaldehyde. After the fumigation the room should be thrown open and well ventilated, and then thoroughly cleansed with a corrosive sublimate, carbolic acid, or hot soda solution, a 4 per cent. solution of the latter being not only cleansing, but strongly disinfectant as well.

Sulphur gas excels formaldehyde in the destruction of such vermin as roaches, bedbugs, fleas, flies, and mosquitoes, and may be preferred to the latter or used as an adjunct to it where there is danger of infection being transmitted by these agents. Likewise, it may be used to destroy larger animals, such as rats and mice, that we now know may be carriers of various disease germs.

*Formaldehyde* (formic aldehyde), both in its gaseous state and in solution, is undoubtedly one of the best and most efficient disinfectants now in use. It has considerable penetrating power, although less than steam or than was claimed for it at first by its more enthusiastic advocates, while for surface disinfection it acts almost immediately. It is, therefore, much better in this respect than chlorine or sulphur dioxide, already mentioned, and where it is properly used, only such articles as bedding, mattresses and pillows, that can be better treated with steam, need be removed from an infected apartment. Clothing, rugs, hangings, etc., that can be freely exposed to it are quickly sterilized. Another important feature is that it does not bleach nor act destructively on either clothing or furniture, and that, although it is quite irritating to the conjunctivæ of the eyes and to other mucous membranes when concentrated, it is virtually non-poisonous.

Formaldehyde is readily absorbed and held in solution by water to the extent of 40 per cent. by weight of the latter, but as soon as this proportion is exceeded there is a polymerization of the gas and a solid (paraformaldehyde or paraform) is precipitated, which is only resolved again into formaldehyde at a temperature of 275° F. The 40 per cent. solution is practically identical with the preparation which is commercially known as formalin, which has usually an addition of 10 per cent. of methyl alcohol to guard further against precipitation. Very weak solutions (1 or 2 per cent.) of the gas are still effectively disinfectant, while its virtue as an antiseptic persists even when the dilution is carried to a remarkable degree.

One peculiar effect of the solutions is that of rendering connective tissue and all gelatinous substances insoluble in either hot or cold water, and it is probably to this that its germicidal activity is largely due, since the food-supply of the bacteria, if not the substance of the latter themselves, is partly of this nature. For the same reason it hardens and disagreeably roughens the skin, which tend to prevent its use for topical applications to the human body.

Several methods have been devised for the production or liberation of formaldehyde in rooms and buildings in such volume as positively to secure both surface and penetrative disinfection. One of the first devised and best methods involves the heating and vaporizing of a solution of the gas, such as formalin or formochloral, the latter a mixture of the former with calcium chloride. For instance, in Trillat's apparatus the latter solution is used, the calcium chloride being added to insure further against the precipitation of paraform. A simpler device, called a regenerator, allows the formalin to flow in a fine stream through a copper coil heated to redness by a flame beneath, the gas and vapor then passing directly into the room in a superheated and effective condition; and in other apparatus, like the Novy-Waite and Trenner-Lee generators, there is special provision for the rapid evolution of the gas at high temperature, and to prevent its polymerization. Both of these methods have the advantage that the apparatus may be operated outside of the room to be disinfected, and the action accordingly controlled; also that the amount of gas liberated depends directly upon the strength and quantity of the solution evaporated.

FIG. 54.

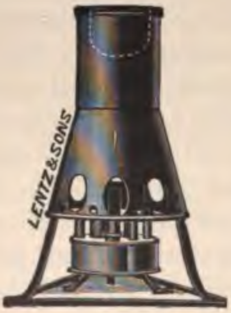
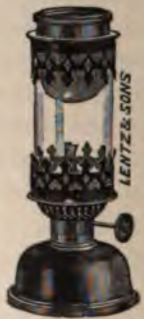


FIG. 55.



Schering's lamps for volatilizing paraform.

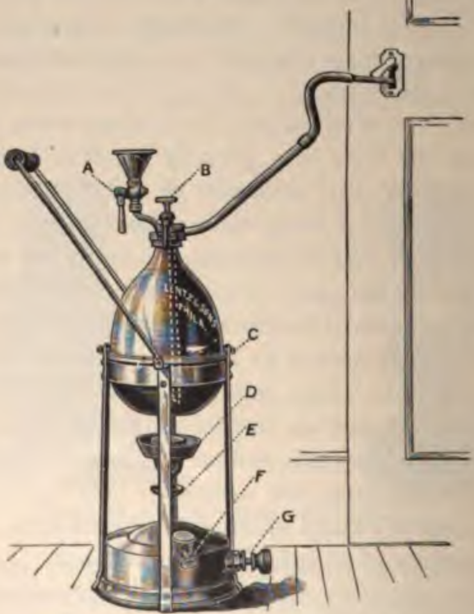
In the Schering method the solid paraform is heated in a receptacle over an alcohol lamp, the volume of resulting formaldehyde depending, of course, upon the amount of paraform used. This method has yielded some excellent results experimentally, and is of special value in disinfecting small rooms, closets, and sterilizing cases for instruments, dressings, etc.

The gas may also be liberated in a room by spraying formalin from a properly constructed compressed air or steam atomizer, or by evaporating it from saturated sheets hung about the room.

Formerly the most common form of apparatus was that devised, in the form of a portable lamp, to develop the gas directly by the oxidation of methyl alcohol, the vapors of the latter being made to pass over or through tubes or coils of heated platinum, and to be thus converted into the disinfectant gas. Considerable formaldehyde can doubtless be produced in this way, but with most apparatus of this kind the amount at any time is uncertain and the results indefinite, since part of the alcohol vapors are polymerized and part are further oxidized into compounds such as carbon monoxide and carbon dioxide. Therefore, with such apparatus, this method is only to be advised for comparatively small apartments or enclosures, and not where certainty of disinfection is important.

However, these objections have been overcome in the Kuhn generator, which is simple and positive in operation and manipulation, and has been proved efficient and reliable under severe tests. In this generator the vapor of alcohol passes between two cones of heated platinized asbestos, one of which is so arranged as to act as a deflector, thus preventing extreme and concentrated heat being thrown directly on the surface of the vessel containing the wood alcohol. Any alcoholic vapor which escapes the action of these platinized cones is then subjected to successive passage through five disks or layers of platinized wire, commercially known as No. 20 mesh, or containing 400 openings to the square inch. In this way the alcohol is brought into thorough contact with a platinized surface, and the result is a much more complete conversion into formaldehyde.

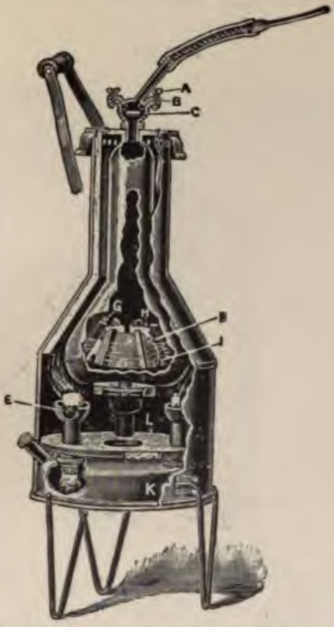
FIG. 56.



Modified Novy-Waite formaldehyde generator.

Abbott states that he has "obtained the most satisfactory results through the use of formalin to which 10 per cent. of glycerin has been added, as recommended by Schlossmann; and through the employment of a generator after the plan of that advised by Novy and Waite. In these tests we found that 80 per cent. of all exposed infected objects in a room could be disinfected when 500 c.c. of the formalin glycerin mixture per 1000 cubic feet of air-space was completely evaporated and the room kept closed for three or four hours."[1]

Fig. 57.



The Trenner-Lee formaldehyde generator.

In the other apparatus one pound of formalin or formochloral, from 50 to 75 of Schering's paraform tablets, or a quart of methyl alcohol are to be respectively used for each 1000 cubic feet of air-space to be disinfected.[1]

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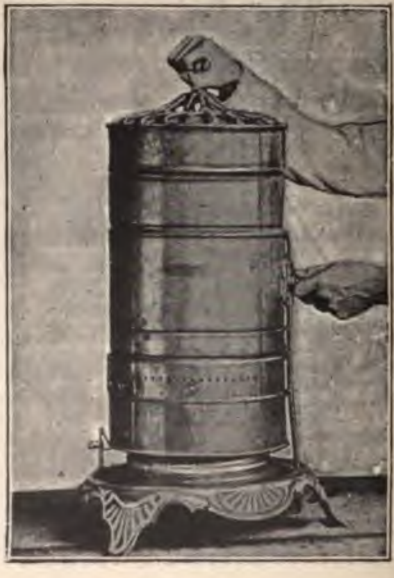
[1] Hygiene of Transmissible Diseases, 1899, p. 269.

Whenever formaldehyde is employed as a gas, all the apertures in the room should be carefully and tightly closed, since, having the same specific gravity as the air, its diffusion takes place rapidly. Moreover, after a sufficient volume of the gas has been liberated, it should be allowed to act as long as possible, preferably for twelve hours at least, and better for twenty-four, since, though it is more rapid, the time element is just as important a factor with this as with other disinfectants. Flügge thinks

FIG. 58.



The Kuhn formaldehyde generator.

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[1] See also U. S. Quarantine Regulations, as quoted on p. 355.

we obtain good results if 90 per cent. of the disease germs present are killed by the formaldehyde fumigation.

Lastly, the gas is an excellent deodorant, combining as it does with the effluvia from decomposing substances to produce odorless compounds. Its odor, in turn, may be quickly dissipated from a room by evaporating a little ammonia therein.

The following table of Koch and Jaeger is added to show the comparative disinfectant strength of some substances occasionally used for the purpose:

| *Disinfectant* | *Strength.* | *Objects submitted to experiments.* | *Time required for destruction.* |
|---|---|---|---|
| Bichloride of mercury | 1 to 20,000 | Anthrax spores | 10 minutes. |
| | 1 to 1,000 | Anthrax spores | 1 minute. |
| Silver nitrate . . . . . | 1 to 12,000 | Anthrax spores | 70 hours. |
| | 1 to 4,000 | Cholera and typhoid | 2 hours. |
| | 1 to 2,500 | Diphtheria | 2 hours. |
| Acid, hydrochloric . . | 2 to 100 | Anthrax spores | 10 days. |
| Acid, sulphuric . . . . | 2 to 100 | Anthrax spores | 53 days. |
| | 15 to 100 | Anthrax spores | 8 days. |
| Ferrum chlorate . . . | 5 to 100 | Anthrax spores | 6 days. |
| Calcium chloride . . | 5 to 100 | Anthrax spores | 5 days. |
| Potass. permanganate | 5 to 100 | Anthrax spores | 1 day. |
| Caustic lime . . . . | 0.0246 to 100 | Cholera | 6 hours. |
| | 0.0074 to 100 | Typhoid | 6 hours. |
| Acid, carbolic . . . . . | 3 to 1,000 | Staphylococcus and streptococcus pyog. | 8-11 seconds. |
| | 10 to 100 | Anthrax spores | 24 hours. |
| Formaldehyde . . . . (K. Walter.) | 1 to 100 | Nearly all pathogenic germs | Less than 30 minutes. |
| | 3 to 100 | Anthrax spores | 15 minutes. |
| | | All other pathogenic germs | 1 minute. |

In any case of infectious disease special attention should be given to disinfecting the excretions and secretions which are known to be most likely to contain the disease germs, viz., the desquamating epithelium and likewise the renal secretion in measles, scarlet fever, and all the exanthemata; the dejecta and urine in typhoid fever, cholera, tropical or infectious dysentery, and in tuberculosis of the intestinal or genito-urinary tract; the sputum in tuberculosis of the lungs and air-passages, and in influenza, pneumonia, and diphtheria; secretions from the throat and nose in diphtheria, scarlet fever and measles; discharges from abscesses, suppurating or gangrenous wounds, etc.

During the course of the illness there should be no more communication than is absolutely necessary between the occupants of the sick-room and those in the rest of the house, and a sheet should be hung at the door and kept moist with some disinfecting solution, as this will largely prevent the escape of infected dust particles through the doorway. All articles going from the room, whether dishes, clothing, or food, should be submerged in a disinfectant or covered with a cloth wet with it, and should be burned, boiled, or otherwise disinfected as soon as possible thereafter. Excreta should be disinfected as soon as discharged from the body, but should not be emptied into a water-closet, sewer, or cesspool till the disinfectant has had ample time to do its work, at least one hour being given for this action. Ventilation should be as perfect as possible; sunlight should be admitted whenever it will not injure or annoy the patient, and, above all, cleanliness in every respect should be insisted upon as being most essential.

The dress of the nurse or attendant should be such that dust and germs do not readily adhere to it and that it may readily be disinfected and cleaned, the cotton uniforms of a hospital training school being almost ideal in this respect. If this were in the form of an overgarment that could readily be slipped off when the nurse has to leave the sick-room, there would be an additional element of safety, just as there will be if there is provided something like a long, old-fashioned linen "duster" for the casual visitor, whether physician or parent, to slip on when entering the room. The nurse should, of course, bathe not only the patient but herself as well with disinfectant solutions, such as Labarraque's (diluted), carbolic acid, or trikresol; should destroy at once all possible infection coming from the patient, and at least every other day should wipe with a cloth dampened in a disinfectant all window-sills, tables, and other horizontal surfaces upon which dust and the attached germs continually settle. A closet with a close-fitting door may be made to serve as a good disinfecting chamber for garments that are not in immediate use, as a few ounces of formalin sprinkled on the garments themselves or a few paraform tablets burned in one of the Schering lamps will quickly sterilize the contents of the closet without serious discomfort to the occupants of the adjoining room.

It is taken for granted that, if possible, before the occupancy of the room by the sick, all upholstered furniture, heavy drapery, and everything not absolutely necessary were removed from the room. Even the carpet should be taken up and rugs used temporarily in its place. If this is done, the work of disinfecting the room after it is no longer needed by the patient will be greatly facilitated.

Where the use of formaldehyde is not available, the final disinfection should be carried out as follows: All bed-clothing, etc., should be either submerged in some disinfectant solution or in boiling water, or else covered with a sheet wet with a disinfectant, and boiled as soon as possible thereafter. No clothing should be sent away from the house to be laundered. Bed-quilts, blankets, mattresses, etc., should be subjected to steam sterilization if possible; if not, the blankets and quilts should be carefully sterilized by boiling, and the mattresses would better be burned, though they may be disinfected internally by the introduction of formalin or formaldehyde gas. The carpet or rugs should be carefully taken up, carried to an open space, well beaten, and then hung in the open air for a time, provided they cannot be sent at once to some place where steam sterilization is available. All furniture and the woodwork of the room should be washed with corrosive sublimate solution (1 to 1000 or 500), taking care to get the fluid into all crevices. The floor may be scrubbed with lye or hot soda solution (4 per cent.), and then mopped and flooded with a corrosive sublimate solution. The walls should also be wiped with cloths wrung out of this solution, and any paper upon them removed before fumigation, unless it be new and free from cracks. Or the walls may be rubbed down with crumbs of bread and the latter burned, as the bread contains much gluten, to which the dust and bacteria adhere. Fumigation with chlorine or sulphur dioxide is usually of somewhat doubtful efficiency unless considerable attention is given to the details. If it is employed, it should be done first, before the bedding, etc., is removed and the walls, floors, woodwork are wiped or washed, and all openings from the room, cracks, crevices, etc., should be closed on the *outside*, and sufficient gas (chlorine or sulphurous acid) liberated by suitable means. The vessels containing the gas-generating substances should be placed in larger vessels containing water to avoid the danger of fire, and vapor of water should be liberated in some way simultaneously with the gas, say by placing hot bricks or the like in the water, or else water should be sprayed freely from an atomizer over everything in the room, as neither chlorine nor sulphurous acid has much disinfecting value except in the presence of moisture, and the effect of formaldehyde is much enhanced by it. The room should then remain closed for twenty-four hours, and, lastly, should be well ventilated for a day or two before being furnished and occupied again.

Should it be possible to use formaldehyde, the disinfection is much simplified, and is to be carried out in the way already indicated; but whatever the gaseous disinfectant employed, it should always be followed by the washing or wiping of walls, ceilings, floor, and all exposed surfaces with a disinfectant solution, and by the steam sterilization or boiling of all removable articles whereever possible. In fact, it should be remembered that no one of these processes will in any probability destroy all the infection, but that each must be carried out with conscientious thoroughness and strictest attention to detail in order to secure the greatest measure of success.

In the foregoing chapter the author is much indebted to A. C. Abbott's Hygiene of Transmissible Diseases for authoritative and up-to-date information as to the value of the agents and methods of infection, and the reader is referred to this work for an abundance of detail which the limits of the present volume do not permit.

# CHAPTER XI.

## QUARANTINE.

QUARANTINE may be described as the methods and measures imposed by a government—local, State, or national—to prevent the introduction of infectious disease into the country or from one locality to another. Although the term in itself is misleading, being derived from the Italian *quarante* (forty), and signifying the period of detention of the first Venetian quarantines, it is now generally taken to indicate the entire routine of inspection, disinfection, and detention, without regard to the length of time involved.

While all civilized nations have from the earliest times recognized the importance of separating those afflicted with epidemic disease from the well, the development of the idea and practice of quarantine has necessarily been consequent upon the growth of commerce; and while there had practically always been isolation for leprosy, the first quarantine enactments, in our meaning of the term, were put in force in Venice about the beginning of the fifteenth century as a barrier to both the black and the Egyptian plague. Then it was realized that epidemic diseases were transmitted by those attacked, a bureau of health and a lazaretto were established, the effects of those who died of the plague were destroyed, and the period of detention of incoming vessels, passengers, and cargoes was fixed at *forty* days, the idea being that this period was in itself more or less mystic and salutary.

As time went on and the plague spread over the whole of Europe, the number of lazarettos was largely increased, especially in the eighteenth century. Of these, the one at Marseilles became the most noted, not only because it was located at one of the most important ports of the Mediterranean, but because of its excellent care and management. Thanks to the increased efficacy of quarantine and other sanitary regulations, as the knowledge concerning them developed, the plague rapidly subsided soon after the beginning of the last century, and interest in it was supplanted by that in relation to the frequent epidemics of cholera and yellow fever that began to alarm the civilized world, and it is to prevent the ingress of these latter diseases, together with leprosy, smallpox, and typhus fever, that the present quarantine regulations are in the main devised.

With the knowledge already gained regarding the nature and causes of infectious diseases, their periods of incubation, etc., it is at once evident that it will be neither necessary nor wise to fix upon a prolonged and arbitrary time during which vessels or passengers must be detained in quarantine. All that is needed is that the proper inspecting officers shall be satisfied that there is no danger of infection entering the country, and, where any detention is necessary, it is only for so long as will suffice for the disinfection of the vessel, cargo, and passengers' effects, and to cover the period of incubation of the suspected disease.

The present quarantine laws of the United States, and the latest regulations of the Treasury Department based upon them, are especially designed to afford the greatest possible protection to the country against the importation of disease with the least possible detention of incoming vessels and passengers. An important innovation that facilitates both these ends has been the establishment of quarantine in foreign lands, as it were, viz., the inspection and, if necessary, disinfection by officers of this government of all vessels, passengers, and cargoes leaving a foreign port for any port of the United States. This undoubtedly greatly diminishes the danger of the introduction of any contagious disease; but in addition, there is that section of the law that provides that the President may, whenever the condition of affairs shall seem to warrant it, "prohibit, in whole or in part, the introduction of persons and property from such countries or places as he shall designate and for such period of time as he shall deem necessary."

Accordingly, every vessel clearing from a foreign port for this country must obtain from the United States consular officer of the port, or from the medical officer appointed for the purpose, a bill of health, "setting forth the sanitary history and condition of said vessel, and that it has in all respects complied with the rules and regulations in such cases prescribed for securing the best sanitary conditions of the said vessel, its cargo, passengers, and crew." Before signing the bill of health the consular or medical officer must be satisfied that the conditions certified to therein are true, and must personally inspect "all vessels from ports at which cholera prevails, or at which yellow fever, smallpox, or typhus fever prevails in epidemic form," and "all vessels carrying steerage passengers." Moreover, the vessel must be clean in all parts before taking on either passengers or crew, and all parts liable to infection must be disinfected if any infectious disease has occurred on the last voyage. The bedding provided for steerage passengers must also be destroyed or else disinfected before being used on another voyage.

The regulations also indicate what kind of cargo, coming from or through infected districts, may or may not be shipped, and what kinds must invariably be disinfected under any circumstances.

As to the passengers, while they are divided into two classes, cabin and steerage, no person suffering from cholera, smallpox, yellow or typhoid fever, scarlet fever, measles, or diphtheria is allowed to ship; nor should passengers ship from an infected port. Steerage passengers and crew who have been exposed to smallpox must be vaccinated before shipping unless they can show proof of immunity by former attack or satisfactory vaccination. If the steerage passengers and crew have been exposed to typhus fever infection, they may not embark until fourteen days after such exposure and the disinfection of their baggage, while steerage passengers from cholera-infected districts must be detained in suitable quarters for five days, "the said period to begin only after the bathing of the passengers, disinfection of all their baggage and apparel, removal of all food brought with them, and isolation from others not so treated." The same rules as to detention and disinfection are to be applied to those coming from places where the plague, yellow fever, or smallpox is prevalent in an epidemic form, and if one of these diseases or cholera breaks out in the detention barracks, there must be a repetition of the five-days' isolation, disinfection, etc., dating from the removal of the last case. Cabin passengers from cholera or other infected ports or districts should produce satisfactory evidence as to their place of abode for the five days immediately preceding embarkation, and if there is any reason for the belief that any one of these or his baggage has been infected, such passenger is to be detained as long as the inspecting officer may deem wise, and his baggage is to be disinfected.

Every passenger must also have an inspection-card, stamped by the consular or medical officer, giving name of passenger, and of ship and port with date of departure, etc.; and all baggage of passengers must have a label bearing the seal or stamp of the United States consular or medical officer, the name of port and of the vessel carrying the baggage, and the statement and date of inspection or disinfection.

It is evident that if these regulations at foreign ports, together with those required at sea—viz., rigorous cleanliness and free ventilation of the vessel, daily inspection by the ship's physician, isolation and disinfection of the sick, etc.—be properly observed, there can be but little chance of the germs of quarantinable disease gaining entrance to our country, and, since the duration of the voyage will in most cases exceed the period of incubation of most of the contagious diseases, if none of these manifest themselves on shipboard at sea there will be no need for any detention at the port of entry beyond that which the inspecting officer stationed there requires for the performance of his duties, viz., to inspect the vessel, bill of health, crew and passengers, and their lists and manifests, he ship physician's clinical record of all cases treated, nd, when necessary, the ship's log.

This inspection service is to be maintained at every port roughout the year, and is in force not only with respect all vessels from foreign ports, but also regarding any vessel with sickness on board, vessels from domestic ports where cholera or yellow fever prevails, or where small-x or typhus fever prevails in epidemic form, vessels from foreign ports carrying passengers having entered a port of the United States without complete discharge of passengers or cargo, and vessels having been treated at national quarantine stations that are located a considerable distance from the port of entry of said vessels. Moreover, the duties of the inspecting officer above stated are only the required minimum standard, and such other regulations may be added by legal State or local authorities as may, for special reasons, be necessary.

If the inspecting or health officer is satisfied that the vessel is not infected and all the foregoing requirements have been complied with, he gives his certificate, to be delivered to the collector of customs of the port, and no vessel is permitted to land any of its passengers or cargo unless it have this certificate, together with the bill of health, etc., from the port of departure, as evidence that the regulations have been properly observed.

On the other hand, if vessels arrive under the following conditions they are to be remanded by the authority of the Secretary of the Treasury to the nearest national or other quarantine station, where proper accommodations and appliances are provided for the necessary disinfection and treatment of the vessel, passengers, and cargo; and only after treatment and after obtaining a certificate from the proper officer that the vessel, cargo, and passengers are each and all free from infectious disease and from danger of conveying the same, can a vessel be admitted to entry to the ports named in the certificate.

The conditions under which arriving vessels are to be placed in quarantine are these: "A. With quarantine disease on board, the quarantinable disease for the purposes of these regulations being cholera (cholerine), yellow fever, smallpox, typhus fever, and leprosy. B. Having had such on board during the voyage or within thirty days next preceding arrival; or, if arriving in the quarantine season, having had yellow fever on board after March 1st of the current year, unless satisfactorily disinfected thereafter. C. From ports infected with cholera or where typhus fever prevails in epidemic form, coming directly or *via* another foreign port, or *via* United States ports, unless they have complied with the United States quarantine regulations for foreign ports; also vessels from non-infected ports, but bringing persons or cargo from places infected with cholera, yellow fever, or where typhus fever prevails in epidemic form, except as subsequently noted. D. From ports where yellow fever prevails, unless disinfected in accordance with these regulations, and not less than five days have elapsed since such disinfection.

"The following exceptions may be made to Rules C. and D. with regard to vessels quarantined against on account of yellow fever: (1) Vessels arriving from November 1st to May 1st may be admitted to entry. (2) Vessels bound for ports in the United States north of the southern boundary of Maryland, with good sanitary condition and history, having had no sickness on board at ports of departure, en route or on arrival, provided they have been five days from last infected or suspected port, may be allowed entry at port of destination. But if said vessels carry passengers destined for places south of this latitude the baggage of said passengers shall be disinfected, and such baggage shall be labelled. (3) Vessels engaged in the fruit trade from ports declared safe for this purpose by the Supervising Surgeon-General of the Marine-Hospital Service may be admitted to entry without detention, provided they carry no passengers and have carried no passengers from one port to another, and have no household effects or personal baggage in cargo, and have complied with the rules and regulations made by the Secretary of the Treasury with regard to vessels engaged in said trade."[1]

Moreover, all passengers other than those occupying first or second cabin, and all persons arriving on vessels that have had smallpox on board, must be vaccinated or detained in quarantine not less than fourteen days, unless they can show satisfactory evidence of recent vaccination or of having had smallpox; and all effects and compartments liable to convey infection must be disinfected.

"No case of leprosy will be landed, and vessels arriving at quarantine with leprosy on board shall not be granted pratique until the leper with his or her baggage has been removed from the vessel to the quarantine station. If the leper is an alien passenger and from a foreign port, action will be taken as provided by the immigration laws and regulations of the United States. If the leper is an alien and a member of the crew, and the vessel is from a foreign port, said leper shall be detained at quarantine at the vessel's expense, until taken aboard by the same vessel when outward bound."[2]

There are ten national quarantine stations and a number of others under State or municipal control; those which have steam disinfection chambers and other efficient equipments are located at Portland, Me.; Boston, New York, Sandy Hook, Delaware Breakwater, Reedy Island in the Delaware River, Cape Charles, Baltimore; Wilmington, N. C.; Savannah, Blackbeard Island, Ga.;

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[1] Quarantine Laws and Regulations of the United States.

[2] Ibid.

Charleston, Dry Tortugas, Key West, Mullet Keys, Pensacola, Mobile, Chandeleur Islands, New Orleans, Galveston, San Diego, San Francisco, and Port Townsend; the ten national ones being included in the list.

The essential requisites for a properly equipped quarantine station, after the selection of a proper location—which should be convenient, but not in the line of future city growth—are the following:[1] 1. A boarding station, including boat-house and boatmen's quarters. 2. A boarding-boat, preferably a steamer. 3. An anchorage for the detention of infected vessels. It should be safely out of the track of commerce, convenient but not too close to the main quarantine establishment, sheltered, and with good holding ground for anchors. 4. A fumigation steamer with appliances for generating and forcing sulphurous acid (or formaldehyde) gas into vessels, and with tanks and pumps for disinfecting solutions. 5. A wharf, in water at least twenty feet deep, and upon which are constructed a warehouse, tanks for disinfecting solutions, and a disinfecting house containing steam disinfecting chambers. 6. A lazaretto or hospital for the treatment of contagious diseases. 7. A hospital for non-contagious diseases. 8. Barracks or quarters for the detention in groups for those who may have been exposed to contagion or infection. 9. Quarters for medical officers. 10. A cremation furnace.

When a vessel is remanded to quarantine by the inspecting officers at a port of entry, its treatment and that of its cargo and passengers will depend largely upon the disease with which it is infected, being more severe if the latter is cholera or yellow fever. In case of infection by either of these diseases the vessel is at once sent to the anchorage, and must remain there until the passengers have been discharged and the vessel purified, and in any case there must be no direct communication allowed between quarantine or a vessel in quarantine, and any person or place outside.

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[1] Rohé's Hygiene.

Moreover, if cholera has occurred on board, all passengers and all of the crew, except such as are necessary to care for her, must be at once removed, the sick to be sent to the lazaretto or hospital, others specially suspected must be carefully isolated, and the remainder separated into small groups, between which there must be no communication. Those who are especially liable to convey infection must be bathed and furnished with sterile clothing before entering the barracks, and no articles capable of carrying infective matter, especially food, should be taken into the barracks. If the disease has occurred in the steerage, all the steerage passengers must be bathed and their clothing disinfected; and in any case all steerage baggage and effects, and any other baggage, etc., that has been exposed to the infection, all articles of the cargo likely to be infected, and all furniture, living apartments, and such other portions of the vessel as may possibly retain or convey infection must be disinfected. The water-supply must be changed at once, the tanks thoroughly disinfected by steam or potassium permanganate solution, and refilled with water from a pure source or with water recently boiled. The water-ballast of a cholera-infected vessel, or of one from a cholera-infected port, should never be discharged in fresh or brackish water without previous disinfection, and the ballast-tanks should be refilled with sea-water or else be disinfected before refilling. Nothing is to be thrown overboard from a cholera-infected vessel in quarantine, but everything that is to be destroyed, even deck-sweepings, should be burned in the furnace.

The disinfection of the holds of vessels is to be by mechanical cleansing, by an acid bichloride of mercury solution (1 to 800) applied under pressure, and by sulphurous acid gas (10 per cent. per volume strength), for from twenty-four to forty-eight hours. All ballast must be discharged or disinfected before the disinfection of the hold, and all solid ballast must be disinfected before being discharged into fresh water. The steerage and forecastle are to be disinfected by live steam, if possible, for at least half an hour, and, if not, by sulphur dioxide and bichloride solution, as was the hold. Baggage, bedding, carpets, etc., are to be removed with caution and to be disinfected by steam or by boiling, and, finally, all woodwork of the vessel is to be thoroughly cleansed mechanically and then washed with an acid bichloride of mercury solution (1 to 1000).

Under date of August 5, 1897, the Secretary of the Treasury issued a circular to State and local quarantine authorities "amending Article 5 of the quarantine regulations to be observed at ports and on the frontiers of the United States, by adding two paragraphs, 8 and 9.

"*Disinfection of steerage, forecastle, and cabin of vessels by formaldehyde gas.* After the removal of the bedding, carpets, and furnishings, all apertures being tightly closed, the steerage, forecastle, and cabin of a vessel may be disinfected by formaldehyde gas in a percentage of not less than 2 per cent. per volume strength, the time of exposure to be not less than twelve hours. The gas may be generated by the following method:

"From an aqueous solution, containing 40 per cent. of the gas, known under the names of formaldehyde, formol, or formolose. The gas is best evolved from these solutions by the addition of from 10 to 30 per cent. of a neutral salt, preferably calcium chloride or sodium nitrate, and heating the mixture in a special boiler. One litre of a 40 per cent. solution of formaldehyde gas will evolve about 1425 litres (50.1 cubic feet) of the gas at 20° C. (68° F.), and will be sufficient for 17 cubic metres (2505.5 cubic feet) of space.

"After the disinfection of apartments by formaldehyde gas the latter should be neutralized by ammonia gas, evolved from water of ammonia by heat, or by evaporation from water of ammonia sprinkled upon the floor. The quantity of water of ammonia required for neutralization, after the above-named method, is as follows: 1¼ litres (1.26 quarts) of water of ammonia for each litre (1.01 quarts) of formaldehyde solution.

"*Disinfection of clothing, bedding, upholstered furniture, articles of leather, etc., by formaldehyde gas.* These may be disinfected by formaldehyde gas in the ordinary steam disinfecting chamber, the latter to be provided with a vacuum apparatus and special apparatus for generating and applying the gas. The gas should be applied in a dry state in not less than 20 per cent. per volume strength, the time of exposure to be not less than one hour.

"The application of the disinfectant can, of course, be modified to suit the circumstances of the case, but the foregoing will be useful as indicating the principles which must be followed."

As to the passengers and others who have been isolated in groups, they are to be inspected twice daily by the physician and remain under his constant surveillance, and can have no communication with any one in a different group or outside of quarantine, except through the quarantine officer. The water-supply and food-supply are to be strictly guarded, and are issued to each group separately. The latter is to be simple in character and abundant in quantity, but no fruit is to be permitted. Strict cleanliness is to be enjoined, disinfection wherever necessary, and, in case cholera or other disease appears in any group, the sick will be immediately removed to the hospital, and the rest of the group bathed and their effects disinfected, and all of them removed to other quarters, if possible. None are to leave quarantine until five days after the last exposure to infection and the final disinfection of such effects as were taken to barracks; and no convalescent may leave quarantine until a bacteriological examination shows him to be free from infection.

As has been stated, the treatment of vessels infected by other diseases is not necessarily so severe as the above, but in each case every effort is made to allow no loophole for the entrance of infection into the country; and in the case of yellow fever there is to be the same isolation of all not required to care for the vessel and a detention of at least five days after disinfection has been thoroughly performed and completed. The detention for typhus fever is to be twenty days, and for smallpox fourteen days, the detention dating from the last exposure to either disease.

No vessel may leave quarantine until she has a certificate from the health (quarantine) officer that she has in all respects complied with the quarantine regulations, and that, in his opinion, she will not convey quarantinable disease. She is then said to be granted *free pratique.*

The law further provides that "when practicable, alien immigrants arriving at Canadian and Mexican ports, destined for the United States, shall be inspected at the port of arrival by the United States consular or medical officer, and be subjected to the same sanitary restrictions as are called for by the rules and regulations governing United States ports; that inspection-cards will be issued by the United States officer at the port of arrival to all such immigrants, and labels affixed to their baggage, as in the case of foreign ports; and where such immigrants are not inspected at the port of arrival they shall enter the United States only at certain designated points on the frontier, and then only after such inspection, detention, disinfection, vaccination, etc., as may be necessary or required by the officers there stationed."

There is also provision for the inspection of State or local quarantines from time to time by the Supervising Surgeon-General of the Marine-Hospital Service, or by any officer of that service detailed by him; and for the observance at all quarantines of such additional rules and regulations as may from time to time be promulgated by him.

**Inland Quarantine.**—Under this heading may be considered the means that may be employed to prevent an epidemic extending from one locality or district to another, although the principle and aims are practically the same as those of maritime quarantines, viz., to define certain boundaries beyond which no person or thing capable of carrying infection may pass, and to establish certain points of ingress or egress on these boundaries where there may be the necessary detention, inspection, disinfection, etc.

The *sanitary cordon* "consists of a line of guards, military or civil, thrown around a district or locality, either to protect the same from the surrounding country when infected, or to protect the surrounding country from the infected district or locality." "It is not intended to bottle up all the people who are caught within an infected district, but, on the contrary, is intended as a means of exit to those who will not carry with them contagious diseases to the people beyond."[1] It may be single or double; in the latter case the inner line closely encircles the well-defined infected locality, and the outer line the whole suspected territory. This latter may be removed as soon as it is evident that the space between it and the inner line is not infected. To be efficient the cordon must be so guarded that, even though it be many miles in length, no unauthorized person may pass through it, while at certain places upon it *camps of probation* or *detention* must be established, where all persons coming from the infected locality may be kept under observation for a time equal to the period of incubation of the disease in question. These camps of probation or detention are to be distinguished from the *camps of refuge*, which were first suggested by Surgeon-General Woodward in 1878, and which are "simple residence camps established to receive the population of an infected community when it has been determined to depopulate the infected district."

At these camps of probation provision must be made for inspecting every person and disinfecting all baggage before entering camp, for isolating the occupants and housing and feeding them in the most comfortable and sanitary manner during the detention, for inspections twice or thrice daily, for the isolation and care of the sick in hospitals at a safe distance from camp, and for the issuance of a certificate granting "free pratique" when the period of detention is over.

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[1] Rohé's Hygiene: "Quarantine."

A notable instance of the sanitary cordon was that about the city of Brownsville, Texas, and along the Rio Grande, in 1882; and of a probation camp, that at Camp Perry, Florida, in 1888.

In addition to these measures it may be necessary or advisable to establish a *railroad quarantine*, as follows: "At certain convenient points, which will be the only points of egress by rail from the infected district, an inspection service and disinfecting station are to be maintained throughout the epidemic. Here all the baggage and freight are to be properly disinfected and all passengers are to be examined by the official inspectors; if the latter are from the infected locality, or have not a certificate from some recognized health officer as to where they have been for the previous days corresponding to the incubative period of the disease, they are to be at once remanded to the nearest camp of probation, there to undergo the necessary detention. Moreover, it may seem advisable to prevent any passenger cars going beyond the infected district, and to disinfect all freight and baggage cars that do so."

There may also be local or house quarantines established by municipal boards of health or other authorities to prevent not only the family or attendants of the sick from mingling with the rest of the community, but also to keep injudicious outsiders from spreading the infection through unwise visitations. And though such isolation may appear at times a hardship to certain individuals, and to be unduly severe, one should not forget the great cost to all concerned of epidemics once inaugurated, nor that it is by such stringent measures that we shall be able to eradicate the infectious maladies from our communities.

The foregoing remarks apply likewise to other prophylactic measures, such as, for example, vaccination. Within the last five years there have been many epidemics of smallpox throughout the whole country, the extent and spread of which were due to a very general neglect to secure the protection afforded by vaccination. To controvert those who assert that this prophylactic measure is of no value, the following statistics are quoted from McFarland and from Harrington: Prior to the adoption April 1, 1875, of the German law requiring vaccination at birth and at the tenth year, the annual mortality in Prussia from 1816 to 1870 was from 7.32 to 66 per 100,000 of population; in 1871 it was 243.2, and in 1872 it was 262.67, owing to the introduction of French prisoners. Since then there has been no epidemic, but from 1875 to 1886 the average annual mortality was 1.91 per 100,000 and the lowest 0.36. On the other hand, from 1870 to 1895 over 20,000 have died from smallpox in Paris alone, where vaccination is not compulsory.

In the following table, note that vaccination was compulsory in the first five cities and not enforced in the other four:

DEATH-RATE FOR SMALLPOX

(in 100,000 of population—1875–1889).

| | |
|---|---|
| Berlin | 1.16 |
| Hamburg | 0.74 |
| Breslau | 1.11 |
| Munich | 1.45 |
| Dresden | 1.03 |
| Paris | 26.24 |
| St. Petersburg | 35.82 |
| Vienna | 64.90 |
| Prague | 147.90 |

According to Harrington, in the Sheffield epidemic of 1887–'88, 1.55 per cent. of vaccinated and 9.7 per cent. of unvaccinated were attacked, the death-rate among the former being 0.7 and among the latter 48 per 1000. Among children under ten the rate of attack was 5 and 101 per 1000 respectively for vaccinated and unvaccinated, and the death-rate was 0.09 and 44 per 1000. From the statistics of this epidemic we have:

RATES OF ATTACK PER 1000 PERSONS.

| | |
|---|---|
| Persons not vaccinated | 94 |
| Persons once vaccinated | 19 |
| Persons twice vaccinated | 3 |

DEATH-RATES PER 1000 PERSONS.

| | |
|---|---|
| Persons not vaccinated | 51 |
| Persons once vaccinated | 1 |
| Persons twice vaccinated | 0.08 |

The same authority states that a "successful primary vaccination within three days after exposure to existing cases of smallpox will prevent the development of the disease, and as late as the fifth or sixth day will either prevent or modify an attack." So that epidemics, even when well under way, can be checked by wholesale vaccination.

However, vaccination should be repeated from time to time, especially when there is danger of infection. In Philadelphia, in 1901–'02, not one of the 1700 smallpox patients treated at the Municipal Hospital had been successfully vaccinated, as evidenced by the scar, within four years of the attack. From the data of this hospital, Welch and Schamberg compiled the following:[1]

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[1] McFarland and Babcock, "Prophylaxis," in Cohen's System of Physiologic Therapeutics.

| | Admitted. | Died. | Percentage. |
|---|---|---|---|
| Vaccinated in infancy (good mark) | 268 | 7 | 2.61 |
| " " " (fair mark) | 83 | 10 | 12.04 |
| " " " (poor mark) | 98 | 14 | 14.28 |
| Vaccinated cases | 449 | 31 | 6.90 |
| Unvaccinated | 465 | 131 | 28.17 |
| Vaccinated after infection | 63 | 12 | 19.04 |
| Total | 977 | 174 | 17.80 |

Surely, with modern statistics such as the foregoing at hand, it is not necessary to recall the excessively high mortalities of the eighteenth century prior to Jenner's discovery, amounting to half a million or more annually in Europe, to convince intelligent persons of the great value of this one method of prophylaxis, and yet legal compulsion seems to be necessary to secure its general employment.

In the preceding pages the author has attempted to present briefly the principles and the regulations of quarantine as practised in the United States at the present time; but the reader is referred for further details to the extremely interesting and valuable chapter on the subject in Rohé's Text-book of Hygiene, by Dr. Wyman, the present Supervising Surgeon-General of the Marine-Hospital and Public Health Service.

# CHAPTER XII.

## THE REMOVAL AND DISPOSAL OF SEWAGE.

THE waste from dwellings is of three kinds: house-sweepings and the ashes from fires; the waste from kitchens, scraps of food, etc., commonly known as garbage; and sewage, the most important, consisting as it does of the solid and liquid excreta of the body, together with waste water from wash-tubs, bath-tubs, kitchens, laundries, etc.

Ashes alone have little effect upon the health, except that they absorb moisture readily, and if allowed to accumulate in a cellar may do much to keep it damp and mouldy. For the same reason, if they be mixed with refuse vegetable matters, putrefaction is favored and noxious emanations given off. The dust from ash heaps may also be carried into the house and largely increase the solid impurities of the air therein. Consequently, ashes should be frequently and regularly removed from the premises.

Kitchen garbage readily decays, and if allowed to remain in the vicinity of the house may pollute both the air and soil about it; but inasmuch as it has some value as a food for animals, there is usually no difficulty in having it removed by scavengers without expense or delay. Care must be had, however, that this is done properly and that all receptacles are kept in as cleanly a condition as possible. Most large cities now find it safer to collect and cremate the garbage at the expense of the municipality, rather than to allow private individuals to keep for its consumption large numbers of animals within or near the city limits. Even though the former plan be the more costly, experience shows that this garbage may and should be consumed in properly arranged crematories at convenient localities without annoyance to the residents of the vicinity, thus saving the expense and time necessary for conveying the garbage beyond the municipal limits.

The kind of waste to which we give the name *sewage* is, however, of more importance to sanitarians, since it is always a possible factor in the production of disease, and since it presents the most difficulties in respect to its removal from dwellings and the ultimate disposal of it.

In addition to the substances already named and which usually come from dwelling-houses, sewage may contain the liquid excreta from stables, the refuse from factories of all kinds, the drainage from polluted soils, and the excess of rain-water not taken up by evaporation or retained in the soil. Its composition must therefore be always complex and variable; but there will be practically always present in it sodium chloride, ammonia, carbon monoxide and dioxide, hydrogen and ammonium sulphide, fetid and decomposing organic matter, and myriads of bacteria. Fresh sewage will not be so offensive to the senses as that in which putrefaction has commenced, nor will the gases arising from it be so dangerous to health. Frankland has shown that "solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo until gas begins to be generated in it"; and it is really doubtful whether the air of a properly constructed and well-ventilated sewer can be shown to contain a harmful excess of injurious gases and organisms. However, it is essential that sewage should always be removed from the premises of a dwelling as soon as possible after its production and before decomposition begins.

When the above-mentioned constituents of sewage are to be disposed of collectively, the *water-carriage* system is usually the best. Although the *pneumatic* system (wherein air-tight pipes extend from the dwellings, etc., to reservoirs from which the air is periodically exhausted and the sewage thus drawn into them) would seem to be advantageous where the topographical conditions do not permit of natural drainage, it is always subject to the danger of breaks occurring and destroying the action, and seems to have been practically successful in but few instances.

A modification of the pneumatic system which seems to be more successful and practical is the *Shone* or *ejector* system. In this the sewage is conducted by gravity through suitable drains to convenient ejector stations or tanks, whence it is forced by means of compressed air to the irrigation fields or other places of ultimate disposal. The system has been in successful operation in Arad, Hungary, since 1896, the plant disposing of the sewage of 20,000 persons from five ejector stations at a working cost, excluding interest and sinking fund, of about 25s. ($6.25) per day.[1]

On the other hand, where house refuse only is to be considered, and where the waste-water can be kept from the other parts of the sewage, or where the water-supply, the physical conditions, or the cost of constructing the necessary sewers prevent the use of the water-carriage method, recourse must be had to the *pail* or *earth-closet* system. The use of primitive privy-vaults or cesspools is most insanitary and dangerous, and should be condemned in almost every instance. Where the necessity for one of the latter seems imperative, it should be made absolutely water-tight, so that none of the contents may escape to pollute the surrounding soil and soil-air or to contaminate the ground-water in the neighborhood. Moreover, the pits should be properly ventilated and should be cleaned out regularly and often, which may be done without offence by some form of odorless excavating apparatus, such as is now commonly used.

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[1] American Year-book of Medicine for 1900, pp. 549, 550.

The daily addition of a solution of chlorinated lime or milk of lime or of sulphate of iron, to the extent of about two quarts for each person using the cesspool, will do much in the way of checking bacterial growth, even though it does not actually disinfect the contents, and will largely prevent the offensive odors of putrefaction from such accumulations. It should be noted that the contents of such a vault, or of a simple pit in the earth, undergo putrefaction rather than natural decomposition, because of the lack of sufficient oxygen supply and of the adjunct action of the nitrifying bacteria which are found only in the uppermost layers of the soil.

It is also probable that many disease germs, particularly those of diphtheria or typhoid fever, will survive and multiply better in the contents of such a vault than in sewage or refuse treated by the methods to be hereafter described.

In the pail system the more solid waste matters, and especially human excreta, are collected in a suitable pail or tub, which, holding only a limited amount, must of necessity be removed and emptied regularly and often. If the outbuildings used for this purpose be kept clean and properly ventilated, such a system will be both economical and healthful.

Advantage may here be taken of the great deodorizing, nitrifying, and oxidizing power of fine dry earth, and various forms of *earth-closets* have been devised to be used in conjunction with the pail system. If a quantity of dry, sifted earth, in bulk about twice that of the dejecta, is thrown upon the latter after using the closet, they will be rendered inodorous and inoffensive. For this purpose loam and clay are best, though sifted ashes may be used with almost as good results, but sand or gravel will not be so efficient as the loam or ashes. Moreover, owing probably to the action of the nitrifying bacteria in the earth, all trace of the peculiar nature of the organic compound is quickly destroyed, and the mixture soon becomes practically nothing but humus, and is an excellent fertilizer.

The pail or earth-closet must, of course, be separate and apart from the dwelling, as it is impossible to have the same means of keeping the gaseous emanations and effluvia out of the house as with the water-carriage system; and it is also important that the liquid house-slops, wash-water, etc., be kept separate from the fecal waste, which should be kept as dry as possible to lessen putrefaction and to increase its possible value as a fertilizer. Nor should this liquid waste be allowed to soak into and pollute the soil about the house. It should be collected in a water-tight reservoir, whence it can be removed at frequent intervals, or, better yet, carried by suitable drains to a kitchen garden or other land at a proper distance from the house, and be there disposed of by irrigation or sub-irrigation.

As one can readily see, this pail system is especially well adapted to isolated houses and small communities, where each householder can take care that the necessary details are properly attended to, and where, as is likely, there is not a general water-supply, or where the expense of constructing the necessary sewers would be too great.

But even in cities as large as Manchester, England, "where four-fifths of the people are obliged to have earth-closets," the system is said to have proved entirely advantageous and practicable.

Where there is a common and general supply of water throughout the house or to a number of houses there must be some provision for carrying off the waste-water, and as this latter will have probably become polluted in its use, it will be advantageous to utilize it to remove the other sewage. In fact, where the conditions are favorable the water-carriage system will usually be found the best of all, because it is more nearly automatic and depends least on human interference and efficiency.

The necessary apparatus comprises, on the one hand, that which belongs to the building and its premises, viz.: the house fixtures, pipes, and drains; and, on the other, the common or public sewers which receive the sewage from the house-drains and convey it to its place of ultimate disposal.

## Sewage-plumbing and House-drainage.

The essence of any good system for the removal of sewage from a dwelling or building is simplicity. Therefore, inasmuch as it has been stated that sewage should always be removed from the premises as soon as possible after its production and before fermentation or putrefaction begins in it, it is evident that in such a system we should have for our object and provide for: "1. The speediest possible removal from the house to the public sewer of excretal and other refuse by means of water. 2. The prevention of the deposit of foul matter in any part of the drainage system and of percolation into the soil of polluting liquids. 3. The establishment of a current of air through every part of the soil-drains and -pipes, in order to disperse any foul gases that may form and to allow them to escape with safety into the open air. 4. The prevention of any entry of air from soil-pipes, drains, and waste-pipes into the house. 5. The exclusion of the air of the common sewer from the house-drains and the house; the last being, perhaps, the most important, as the air of the public sewer may at any time contain the active germs of specific disease."[1]

The attainment of the above requirements is to be secured in the manner to be described. The *soil-pipe* is that which receives the sewage from water-closets and, usually, from the waste-pipes of other fixtures, such as bath-tubs, wash-stands, sinks, etc., and which connects them with the *house-drain;* the latter is the conduit connecting the soil-pipe with the sewer. *Waste-pipes* convey the contents of wash-stands and other fixtures to the soil-pipes or to a branch of the house-drain. (See Fig. 59).

The soil-pipe is usually located almost entirely within the house, although, were it not for the danger of its contents freezing, it would be better to have it fastened to the wall outside. It is made of cast or wrought iron, should be at least four inches in diameter, should convey the sewage as directly as possible from the fixtures to the house-drain, and must extend unobstructed from the latter to several feet above the roof, ending where winds and currents from high walls and chimneys will not interfere with its free ventilation. Every branch of the soil-pipe more than eight feet in length, or to which two or more water-closets are connected, should also be extended above

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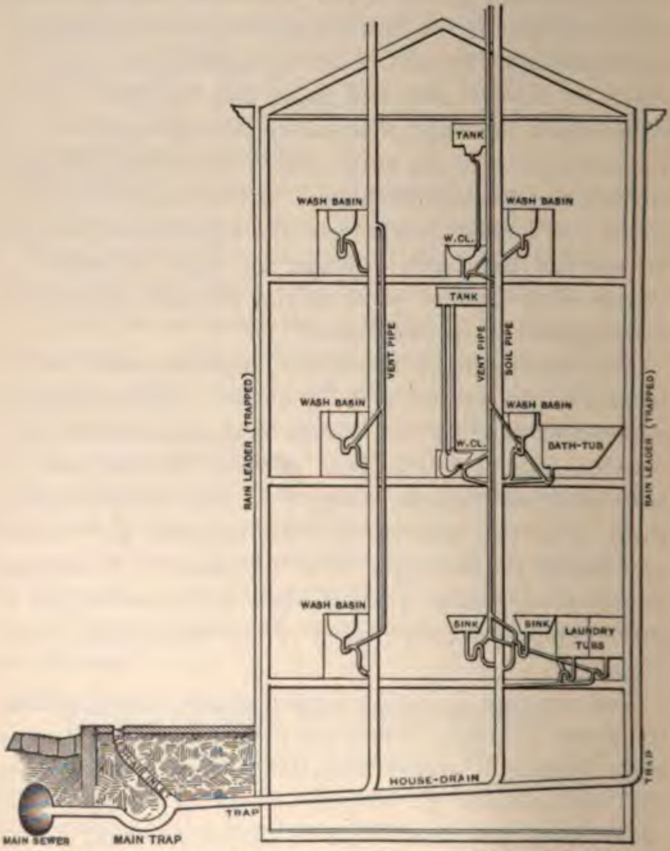
[1] L. C. Parkes, Hygiene and Public Health, 2d edition, p. 139.

FIG. 59.



Illustrating sewage-plumbing of a house. The traps of the rain-leaders at their junctions with the house-drain have been accidentally omitted.

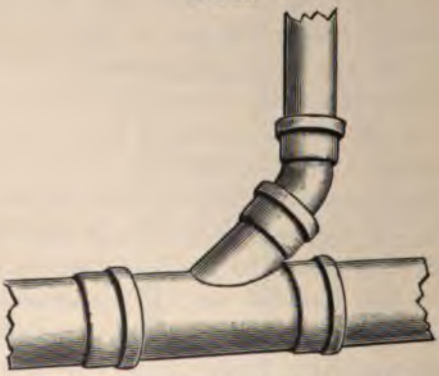
the roof, or else be extended and connected to the main soil-pipe above the highest fixture connected therewith, as there must be no closed ends wherein foul or stagnant air may collect. All joints must be absolutely air-tight, and the pipe must be so secured that any vibration or settling of the building will not be likely to destroy its continuity. In new buildings, especially, all soil-pipes should be exposed or else covered in with panels easily removable at any time to permit of inspection or repairs. Any hidden pipes or those difficult of access should be of extra heavy materials, and extra care should be given to the joints and supports. The soil-pipe and house-drain should both be as smooth as possible interiorly, and in the construction they must be carefully inspected to prevent any of the material used in caulking or cementing the joints from projecting within to prevent the free flow of sewage.

Outside of the house the house-drain may be of iron or of glazed and impervious earthenware, but no earthen pipe should be permitted within five feet of a foundation wall, and where any part of the house-drain is within the building it should be of iron and securely fastened to the foundation-wall above the cellar floor. The connection between it and any soil-pipe should be by means of a rounded elbow, and not by an abrupt right angle. (Fig. 59.) The house-drain should not be less than four nor more than ten inches in diameter, should be laid on a firm foundation, should have air-tight joints, and should have a slope toward the sewer of at least one-half inch to the foot.

If a house-drain empty into a sewer of the "combined" system, there must be a trap just before its junction with the sewer to prevent the passage of sewer-air back into

the house (Fig. 61), and there must also be an opening f
fresh air between this trap and the house-drain, so th
there may be a constant current of air through the hous

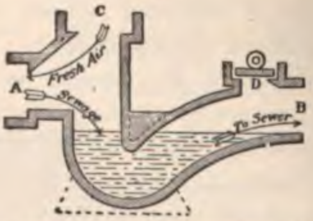
Fig. 60.



Method of connecting soil-pipe with house-drain.

drain and soil-pipes to the exit above the roof, and t
air in the soil-pipes thus kept from becoming foul an

Fig. 61.



Main trap to be placed between sewer and cesspool, or between house-drain
and main sewer. (Notter and Firth.)

stagnant. But if the house-drain empties into a sewe
of the "separate" system, there need be no trap betwee
the drain and sewer, for reasons to be hereafter stated

however the fresh-air inlet between sewer and house-drain is always advisable, as it tends further to assist ventilation.

A house-drain should not empty into a cesspool unless it is absolutely necessary, and in such case the cesspool must be well ventilated and also separated from the drain by a fresh-air inlet and trap, just as when the drain empties into a combined sewer. Nor should any cesspool empty into a sewer.

Where rain-water conductors empty into house-drains or sewers, they should be separated from the latter by traps having a seal of not less than five inches, to prevent sewer-air passing up through them to the vicinity of windows, etc. So, also, all waste-pipes and other pipes opening into house-drains should be trapped.

In the house all water-closets and other fixtures should be as near the soil-pipe as possible that there may be no long stretches of foul waste-pipe underneath the floors, and all connections with the soil-pipe should be made at an acute angle that the discharge into the latter may not interfere with its free ventilation. Each fixture must be separately trapped, and the trap must be located as near its fixture as possible. There must be no connection between a fixture and the soil-pipe or house-drain which is not trapped.

A little reflection will show that by observing the above rules of construction provision will have been made for each of the five specified requirements of the system, and the air in the soil-pipes will be almost as pure as that of the house itself. The absorption of foul gases by the water in the house-traps and their subsequent dispersion into the atmosphere of the house will also be almost impossible. But there must always be free communication between the air inlet into the house-drain and the outlets from and at the top of the soil-pipes; otherwise the air in the soil-pipe cannot be changed and foul gases will accumulate which, by their pressure, would tend to force themselves into the house whenever an opportunity occurred, and might even overcome the seal of some of the traps.

*Traps* are "appliances placed between house conveniences (fixtures) and soil-pipes and drains or sewers, to prevent sewer-gas gaining an entrance into the house." Most traps are too complicated. The simpler a trap the better, provided it have sufficient seal. The seal of a trap is the depth of water or the mechanical appliance which prevents the back-flow of gas. Mechanical appliances are liable to become clogged and not to fit tightly, thus allowing the passage of sewer-air; they also tend to check the free onward flow of the sewage, thus favoring deposition in and preventing the cleansing of the trap. The S or siphon trap is as simple as any, is of uniform diameter throughout, has no corners or projections to catch dirt, and is thoroughly cleansed by each fair flow of water through it. The value of a trap does not depend

FIG. 62.

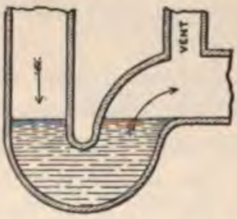
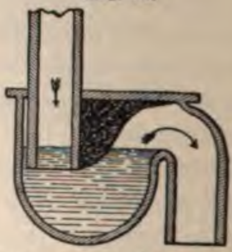


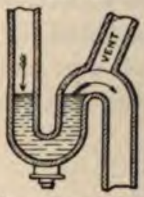
FIG. 63.



These illustrations show how a uniform calibre prevents the accumulation of dirt in a trap, and how angles and corners favor such accumulations. (GERHARD.)

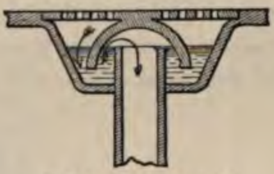
so much on the amount of water it contains as on the depth or strength of the seal. On account of evaporation the water-seal of a trap may become lessened or destroyed unless the fixture to which it is attached be in frequent use; it is therefore advisable to have as few fixtures of any kind in the house as the comfort or convenience of the inmates will allow. So, also, if a house is to be unoccupied for a time, it is well to cover the water in the traps with oil or glycerin to prevent evaporation of the former. Leakage or capillary action, the latter caused by accumulations of hair, thread, etc. in the trap, may likewise lower the water so that sewer-gas may pass through from the soil-pipe.

FIG. 64.



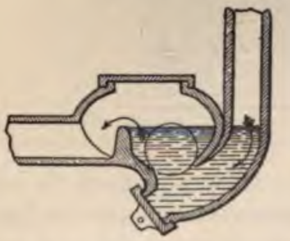
S or siphon trap, with opening for ventilation-pipe. (GERHARD.)

FIG. 65.



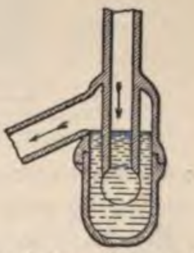
Bell trap. (GERHARD.)

FIG. 66.



Cudell's trap. (GERHARD.)

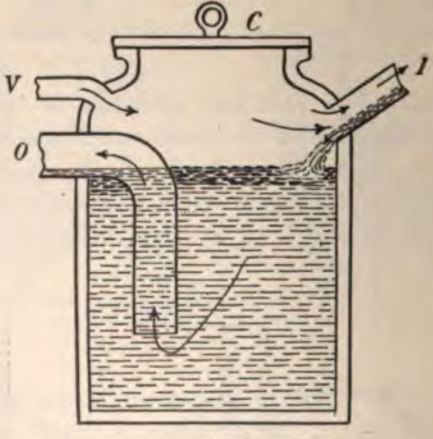
FIG. 67.



Bower's trap. (GERHARD.)

Lastly, the seal of a trap may be broken by siphonage, either by a strong rush of water through it from its own fixture, or by a rush down the soil-pipe from a fixture higher up, and this is especially liable to occur if the trap be some distance from the soil-pipe, or if the fixtures above discharge a large amount of water at once. To prevent this, openings are sometimes made at the top of the traps on the side next the waste-pipe or soil-pipe and connected with vent-pipes, which should open into the soil-pipe above the entrance of the waste-pipe from the highest fixture, or be continued separately into the out-door air. (See Fig. 59.) But this greatly increases the expense, and, as the vent-pipes, to be efficient, must be almost two inches in diameter, they also favor evaporation from the trap. If the trap is properly constructed, if the soil-pipe is of suitable size and height, and if the fixtures be placed as near the soil-pipe as possible, there will be but little

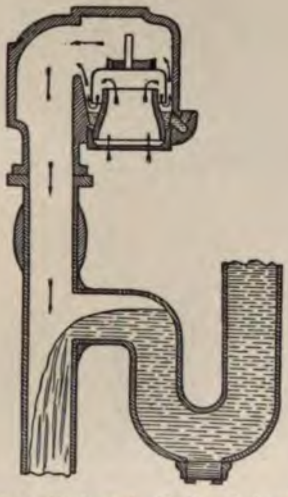
FIG. 68.



Grease trap. (HARRINGTON.)

danger of siphonage occurring. Where it does occur, McClellan's anti-siphon attachment (Fig. 69) is said to work advantageously, being inexpensive and permitting a free ingress of air to the trap, but no egress of air from the soil-pipe into the house. In this device a small weighted and inverted cup rests with its edge immersed in a ring of mercury, from which it is raised by the

FIG. 69.

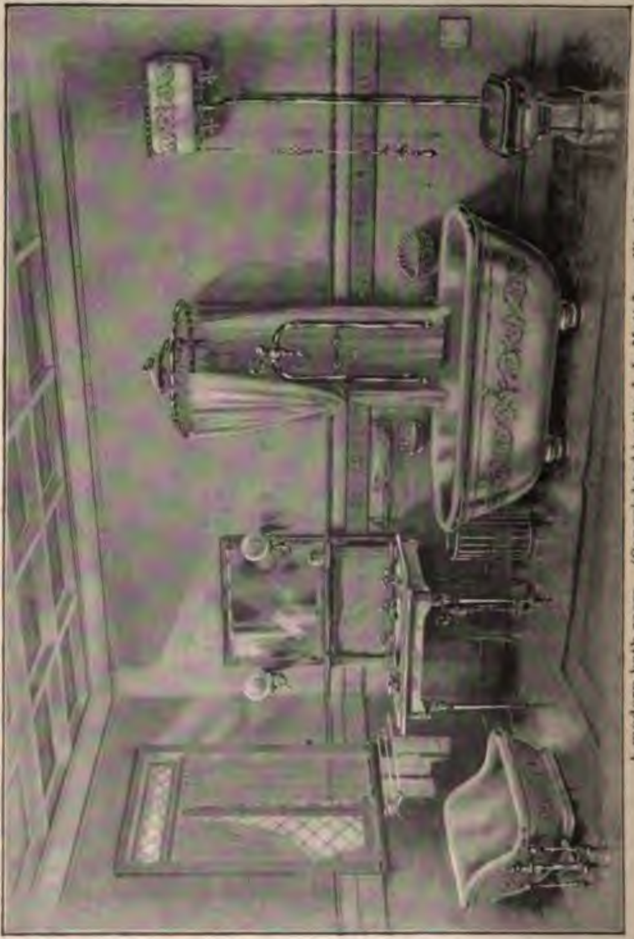


McClellan's anti-siphon attachment. Sectional view of vent with cup lifted out of the mercury by the inflowing current of air, indicated by the arrows. (ROHÉ.)

atmospheric pressure only when the siphonage sufficiently reduces the pressure within the pipes. The mercury and the weight of the cup make a seal sufficient to prevent any outflow of gas. It is also said that if the waste-pipe be connected with the soil-pipe by a divergent opening, siphonage will be less likely to occur.

All waste-pipes, soil-pipes, and house-drains should be tested before use by closing all openings and forcing in air to a pressure of at least thirty pounds to the square inch. Leaks may be detected by plugging the lower openings and filling the pipes with water, or by pouring

FIG. 70

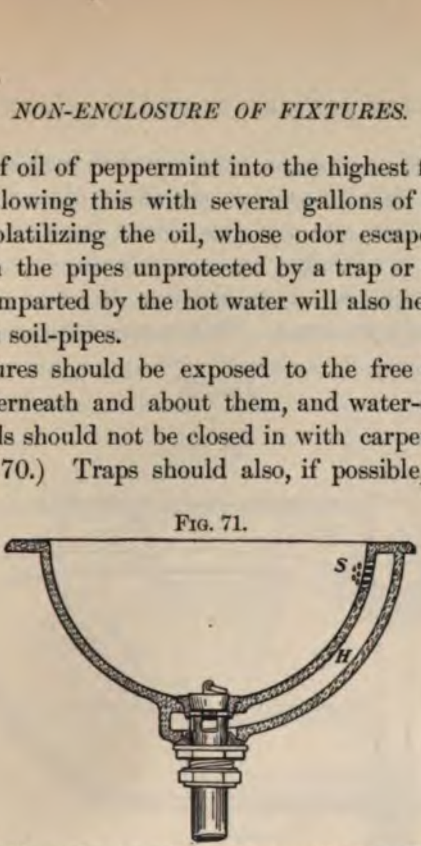


A modern bath-room. (Copyrighted by the J. L. Mott Iron Works Co.)

an ounce of oil of peppermint into the highest fixture and quickly following this with several gallons of hot water, the heat volatilizing the oil, whose odor escapes at every opening in the pipes unprotected by a trap or water-seal. The heat imparted by the hot water will also help to trace out hidden soil-pipes.

All fixtures should be exposed to the free ventilation of air underneath and about them, and water-closets and wash-stands should not be closed in with carpentry work. (See Fig. 70.) Traps should also, if possible, be where they may be opened and inspected at any time. Under each closed-in fixture, if there must be such, there should be a drip-safe to catch any leakage or overflow of water, but the pipes, if any, leading from these should never empty into waste-pipes or soil-pipes; they should lead preferably into the open air and not to the cellar, as the cellar-air, which is usually impure, thus gains access to the house. Even if these drip-safe pipes are trapped and open into the soil-pipe, the water in the trap is replenished so rarely that evaporation soon destroys the seal and allows the air to pass from the soil-pipe into the house.

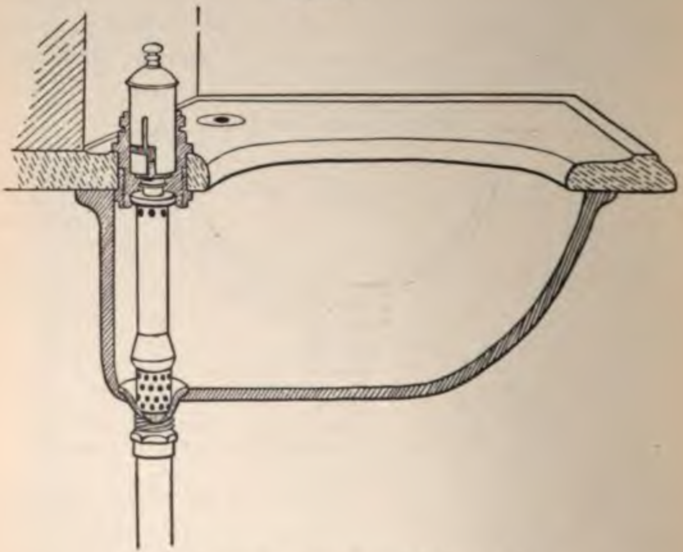
FIG. 71.



Wash-basin with overflow horn discharging beneath plug. (HARRINGTON.)

The overflow-pipe of old-fashioned wash-stands and bath-tubs is objectionable, as it collects dirt of all kinds, soap, epithelium, etc., and it is almost impossible to clean it. Beside, it will often be found opening into the waste-pipe *below* the trap, thus allowing the free passage of sewer-air into the room. When new fixtures are being put in they should preferably be such as make use of the stand-pipe principle in the stoppers and that have no separate or concealed overflow-pipe or outlet.

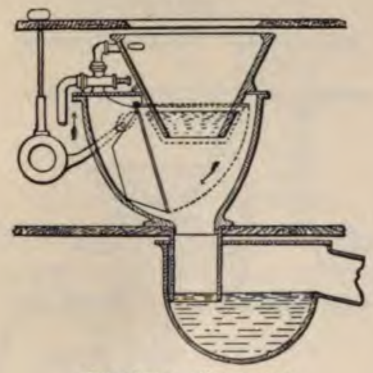
FIG. 72.



Improved stand-pipe overflow. (HARRINGTON.)

**Water-closets.**—The requisites for a good water-closet are: that it does not allow the escape of sewer-air from the soil-pipes into the house; that it is thoroughly and easily cleaned each time after use; that there are no hidden parts in which filth can collect, or which cannot be readily cleaned; that the flushing or washing out of the closet be done in such a way that dirt or spray be not thrown into the air of the room; that there be sufficient water-supply to wash out the bowl and trap each time and to refill them to the proper level; that the trap itself is not siphoned or left empty by a discharge of water from this or another fixture.

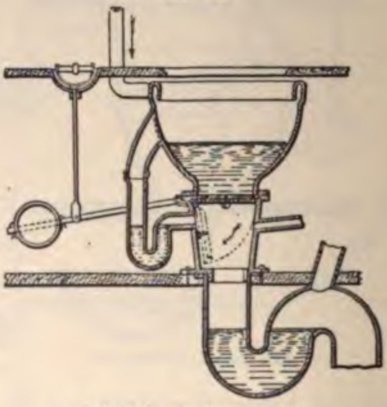
FIG. 73.



Pan closet. (GERHARD.)

Of the different kinds of water-closets the pan and the valve closets are the oldest and the worst, and should not be used. They consist of a receiving bowl, the bottom of which opens into a swinging pan or is closed by a valve. The pan or valve and the lower part of the receiving bowl are enclosed in another bowl, the container, connected with the soil-pipe and trap. The depth of water in the receiving bowl in pan closets is regulated by the depth of the pan, and in valve closets by the location of an overflow outlet. In both kinds the contents of the receiving bowl are discharged into the container by the tipping of the pan or valve, and consequently the sides of the container, as well as the under side of the pan or valve, soon become thickly coated with filth. This, being hidden, accumulates, decomposes, and contaminates the air in the container, which air is of necessity discharged into the room as often as it is displaced by the contents of the receiving bowl. In valve closets the overflow-pipe from the receiver furnishes an additional way by which the foul air may pass from the container into the atmosphere of the room. It needs no argument to show that these closets are decidedly dangerous to health.

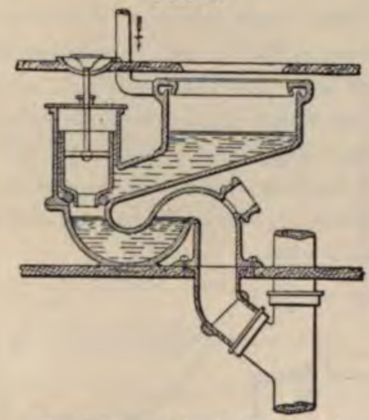
Fig. 74.



Valve closet. (Gerhard.)

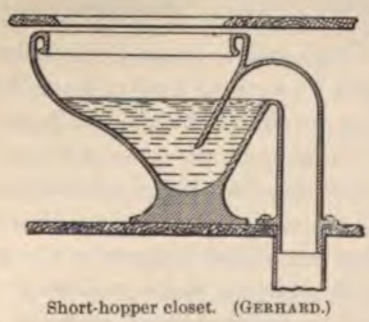
Plug or plunger closets are those in which the outlet above the trap is stoppered by a plunger, this being usually in a chamber at the side of the receiving bowl. The bowl and side chamber holding a considerable quantity of water, the trap is well flushed out each time of use; but the side chamber and plunger, being hidden and not easily cleaned, soon become coated with filth and dangerous to health, as there is nothing to prevent the air from passing from this chamber into the room. Moreover, the plug may not close the opening completely, thus allowing a continual waste of water. A trapped overflow-pipe in the plunger keeps the closet from overflowing.

Fig. 75.



Plug or plunger closet. (Gerhard.)

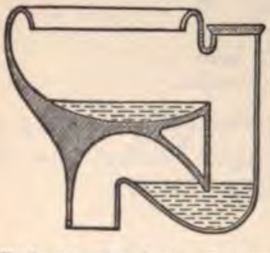
Fig. 76.



Short-hopper closet. (Gerhard.)

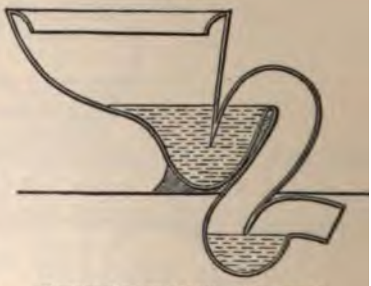
Hopper closets consist simply of a bowl connected below with an ordinary trap, and, as there is nothing to get out of order, this kind is theoretically one of the best. T objection to long hoppers is that dirt is apt to stick to t sides and become offensive, but this can be prevented if is so arranged that water begins to flow down the sides soon as the closet is put to use, thus preventing adhesio Short hoppers have not this objection, as the feces fa directly into the water in the bowl and are carried o through the trap as the bowl is flushed. All water-close should have a flushing rim encircling the top, so that a sides of the bowel may be washed down and cleansed eac time the closet is used.

Fig. 77.



Wash-out water-closet. (Parkes.)

Fig. 78.



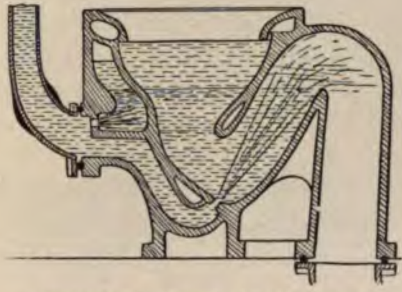
Dececo siphon closet. (Parkes.)

Wash-out closets retain considerable water in the bowl and are emptied by a strong flush of water from the flushing rim. They are simple, do not readily get out of order and are much in favor at the present time. As they ar a modification of the short-hopper closet, so is the siphon closet a modification of the wash-out variety.

In the siphon closet the contents of the bowl and tra are lifted out by siphonic action, and then the bowl an trap are refilled, as in the case of wash-out closets, by a after-flush. In the Dececo closet—a siphon closet—us is made of the principle involved in the Field flush-tank.

Hopper, wash-out, and siphon closets should be supplied from water-closet cisterns, which should give a certain and sufficient volume of water with only a short pull on the chain. The bowl and trap should also be automatically refilled from the cistern after use.

FIG. 79.



Sanitas siphon closet. (HARRINGTON.)

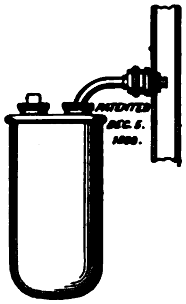
Water-closets should not be connected directly with the water-supply pipes of the house, as air from the closets may be sucked into them at times when the water-supply is cut off, and the water afterward contaminated by it. But this is difficult to avoid in pan, valve, or plug closets, and is another serious objection to their use.

Vent-pipes from the bowl and seat of water-closets must be large, and must not open into the soil-pipe, but into the open-air; they must not open near a window nor any place from which air is taken into the house, but may open into a flue which is constantly heated, as a kitchen chimney, or may themselves be heated and have a current maintained in them by a small lamp or gas-jet. In this way the room in which a water-closet is located may be effectively ventilated.

Water-closets should never be placed in dark closets, nor in bed-rooms or living-rooms, but should always be in separate rooms that have free communication with the open air by means of a large window or by a ventilating shaft of at least four square feet sectional area throughout its length. It is also advisable that bed-rooms should not communicate directly with bath-rooms, etc., containing water-closets, unless there is every assurance that the closet and plumbing connected with it are first-class in every particular.

A recent device which is intended for attachment to the flush-pipes of water-closets and to the waste-pipes of other

Fig. 80.

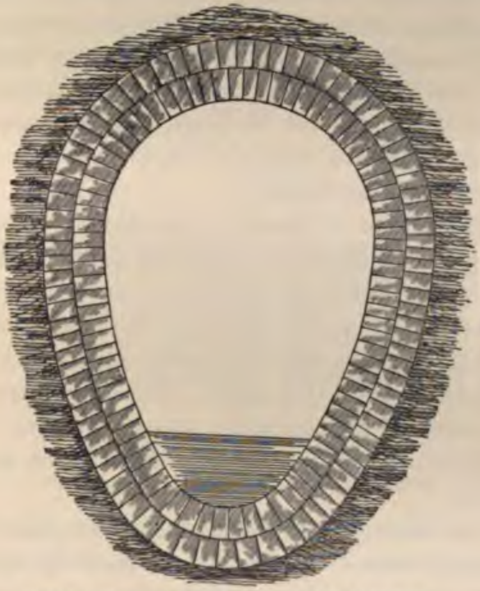


Automatic injector for disinfecting traps, water-closets, etc.

fixtures between them and their traps, automatically discharges with each flow of water through the respective pipes a sufficient quantity of an antiseptic to prevent all growth of micro-organisms in the traps or their contents. (Fig. 80.) This, when used, aids not only in obviating the escape of harmful or disagreeable gases into the house, but also largely prevents the addition of disease germs to the contents of the public sewer.

**Sewers.**—These are the conduits provided to receive and convey the contents of house-drains and other drains to the place of final disposal or discharge. They may be of either of two kinds—*combined* or *separate*. Sewers of the first class, which have heretofore been most commonly used in this country, are constructed to carry off all kinds of sewage, the waste liquids, etc. from factories, street-washings, and the surplus rain-water of the district drained by them. As this necessitates a size and capacity sufficient to receive the greatest probable rainfall upon the area drained in addition to the other sewage, it is evident that the depth of the usual daily volume of the latter in the sewer will be so shallow and the current so sluggish as greatly to favor the settling of the

FIG. 81.



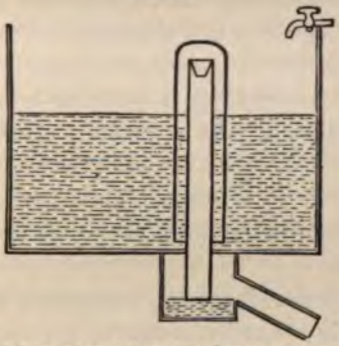
Section of ovoid sewer of "combined" system.

solid and semisolid constituents, the obstruction of the sewers, and the development of bacteria and sewer-gas. To obviate these faults and to insure a more rapid flow by keeping the depth of sewage as great as possible, the smaller conduits at least are generally made ovoid in section, the smaller end, of course, being downward. Combined sewers are not only more expensive to construct and to keep in repair than those of the separate system, but greater care must be had to see that they are at all times properly ventilated. The main advantage claimed for them is that the expense of constructing separate conduits for factory wastes, street-washings, and the excess of rain-water is avoided; but this is a doubtful one both in respect to economy and sanitation.

The ventilation of sewers of this kind is usually sufficiently provided for by the inlets for street-washings and rain-water, located at street-corners, etc.; but if these are not close enough together to keep the sewer atmosphere constantly changing and reasonably pure, other ventilation openings should be made. But in all cases the air from sewers of the combined system must be excluded from house-drains, etc., by the traps which have been described.

To the sewers of the separate system only the sewage proper from dwellings, and occasionally from small factories, is admitted, the rain-waters, surface-waters, and soil-waters being removed by other drains or channels. The advantages of this system, which is now indorsed by almost all sanitarians, are that the volume of sewage to be carried is comparatively small and constant, and that it can be calculated very approximately from the daily water-supply and population; that the cost of construction is much less than that of sewers of the combined system, and that, while it is available and satisfactory for large cities, it is the only one that small communities would consider or can afford; that the sewage is more concentrated and uniform in composition, and can thus be better utilized as a fertilizer or disposed of in whatever manner may be most sanitary and advantageous; that the sewers, having smaller peripheries and smoother walls, are more frequently and effectually flushed, and that they are more completely ventilated and altogether better suited to the work to be performed. The disadvantages of sewers of this class are that a community must have two sets of drains, one for sewage and the other for rain, street, and factory waters, and that after a protracted dry season the street-washings, etc., may be very foul; but these are outweighed by the advantages above mentioned.

FIG. 82.



Field's annular siphon flush-tank. (PARKES.)

"No sewer of this system should be more than six inches in diameter until it and its branches have accumulated a sufficient flow at the hour of greatest use to fill this size half-full, because the use of a larger size is wasteful and because ventilation becomes less complete as the size increases. The size should be increased gradually and only so rapidly as is necessary by the filling of the sewer half-full at the hour of greatest flow; and the upper end of each branch sewer should be provided with an automatic flush-tank (Fig. 82) of sufficient capacity to secure the thorough daily cleansing of so much of the conduit as from the limited flow is liable to deposit solid matters by the way."

There should ordinarily be no traps between house-drains and sewers of the separate system, since, having no rain-water inlets, the latter would otherwise have no openings for ventilation. Moreover, since the "separate" sewers are so regularly and thoroughly flushed, the air in them is not likely to be so impure, and there is not the same reason for excluding it from the house-drains, etc., as there is regarding the air from "combined" sewers. The junction of house-drains with sewers of the separate system should be by divergent openings, so that the air may pass freely into the drain as the sewage empties into the sewer.

Should one desire, however, to separate his house-drain from the public sewer by means of a trap, and thus prevent the ingress of sewer-air into his premises, the ventilation of the sewer can be secured by providing a vent-pipe between the trap and the sewer. But in no case must the inlet-pipe for air on the other side of the trap, between it and the house, be omitted; nor should the two air-pipes be so near together that air from the former will be likely to be drawn into the latter.

All sewers should be laid on a good foundation with sufficient fall to give at least a velocity of two feet per second to the flow. If made of brick, they should be laid in a mortar made of cement and sharp sand, and all sewers should be as smooth as possible inside to prevent the arrest of particles of sewage. Sewers of the combined system should not be pervious to the soil-water, as the liquid sewage is just as apt to pass from them to the soil and to pollute it dangerously as the soil-water is to pass into the sewers. But the rain-water drains of the separate system may also be employed to drain the subsoil.

**The ultimate disposal of sewage** is a matter of considerable importance which commonly does not receive the attention it deserves. The usual method in this country of discharging the sewage into a running stream is reprehensible, because the natural purification of a water thus contaminated must always be slow and more or less uncertain, and because the risk to those using the polluted water must be a constantly increasing one. Where the district drained and supplied by the stream is a sparsely settled one, and where the volume of fresh or running water is very large in proportion to the quantity of pollution it receives, the objections to the disposal of sewage in this way may be theoretical rather than practical; but as the population increases and the ratio of pure water to filth decreases beyond certain limits, the question becomes more serious and pertinent. It is said that to dilute safely the sewage of 1000 persons requires from two to four million gallons of unpolluted water per day; this, of course, not destroying the disease germs nor eliminating the danger of their multiplication.

Other methods of sewage disposal resemble closely those already described for the purification of water, in that they make use of subsidence, chemical treatment, and filtration. The sewage may be collected in large tanks, with or without the addition of certain chemicals, such as lime, alum, or sulphate of iron, to increase the cipitation, and the suspended impurities allowed to ttle to the bottom of the tanks, whence they can be emoved, squeezed partially dry in hydraulic presses, and either disposed of as a fertilizer or cremated. The clear ffluent or liquid part of the sewage may be allowed to ow at once from the settling tanks into a convenient watercourse, provided it is there well diluted, or it may etter be filtered through an area of porous soil or through repared filter-beds. If the filtration is properly done, the iltrate will contain nothing harmful, and may be allowed to flow where it will without danger. A properly prepared filter-bed of twelve inches of sand upon eighteen inches of gravel or magnetic carbide of iron, with an area of one acre, is said to be able to purify from one to two million gallons of clarified—effluent—sewage in twenty-four hours.

Chemical treatment will probably cost from thirty-five to fifty cents or more per annum per individual of the population supplying the sewage, but an even more important question than cost is whether the addition of the chemicals may not interfere with the natural biologic processes of purification constantly taking place in most sewage. Chemicals that are or have been used as precipitants are lime, lime with alum, sulphate of iron or alkali waste, sulphate of iron alone, and a combination of alum, charcoal, and clay. The precipitate obtained with the latter makes a superior fertilizer.

Sewage may also be disposed of by intermittent downward filtration, either through specially constructed filter-beds or a prepared area of soil; by irrigation or subirrigation, and by the so-called septic-tank method.

For sewage, intermittent filtration is superior to the continuous process—in fact, is almost essential, as the interruption in the percolation permits a renewal of the air-supply in the filtering medium or soil, and thus furnishes a sufficient quota of oxygen for the oxidation and nitrification of the excessive amount of organic matter in the sewage. With sufficiently frequent intermittence, fine sand, such as is used for building purposes, makes an excellent artificial filter, capable, it is stated, of purifying 50,000 gallons of crude sewage per acre per day and of removing all the solids, much of the dissolved matters, and 99 per cent. of the contained bacteria. Where the crude sewage is allowed to settle or is treated biologically in the septic tanks, a much greater quantity of the clarified effluent can be filtered daily, as is indicated above.

By intermittent soil filtration we mean "the concentration of sewage at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine qua non* even in suitably constituted soils whereever complete success is aimed at."[1] The land should be levelled and under-drained with tile drains at the depth of five or six feet, and should be divided into four parts, no part to receive sewage for more than six hours. An acre of properly prepared soil will thus dispose of the crude sewage of 1000 to 2000, or the clarified sewage of 5000 people.

The soil to be used for this purpose, as well as that for irrigation and sub-irrigation, should be porous and loamy; if clay, it should be well broken up and mixed with ashes; sand does not purify sewage well, especially at first, in these methods. The sewage impurities are removed partly by mechanical filtration, but especially by oxidation, the latter being due partly to the air in the interstices of the soil, but chiefly to the saprophytic bacteria, which rapidly convert the organic impurities into ammonia, nitrates, nitrites, and other simple compounds.

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[1] Metropolitan Sewage Commission; see Notter and Firth, p. 546.

Irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation, consistently with due purification, for the amount of sewage supplied."[1] Sub-irrigation is a modification of this, the sewage being delivered through porous drains a few inches beneath the surface of the soil. Unless very porous, the land should be under-drained; it should also be levelled to prevent the sewage flowing off the surface too rapidly. The under-drains need not be nearly so close together, however, as in the intermittent filtration system. The crops raised on irrigation farms are healthful in every respect, and there can be no reasonable objection to their use as food; there would be decided objection, however, to sprinkling the vegetables with sewage water.

On the large irrigation farms of the city of Berlin the cost of sewage disposal is about covered by the returns from the crops raised upon them. The mortality of those employed upon them is very low, and there seems to be no particular tendency to illness that can be attributed to the sewage. It is even said that the employés use with impunity the clear water in the effluent canals for drinking and other purposes. Paris has also adopted the irrigation method, and hereafter the sewage of the entire city will be treated in this way. The sewage of from 100 to 150 persons per acre may be satisfactorily disposed of by irrigation, Berlin's rate, with an especially favorable soil, being 142 per acre. It is to be especially recommended for isolated houses, for small communities, or for charitable or other State institutions.

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[1] Metropolitan Sewage Commission; see Notter and Firth, p. 547.

The "septic tank" system for the disposal of sewage particularly aims to take advantage of the biologic and saprophytic action occurring naturally in all polluted waters. The idea is to favor, and not to hinder the purifying bacteria and other agencies by placing the sewage under the conditions most favorable to their growth and action, thus facilitating the conversion of organic matters, both solid and dissolved, into substances entirely harmless and unobjectionable. In other words, advantage is to be taken of the action of both the anaërobic and aërobic saprophytes which abound in all sewage that is not too strongly impregnated with antiseptic chemical wastes from factories or other sources. In the intermittent filtration and irrigation methods of sewage disposal the service of the anaërobic organisms is practically eliminated because the success of these methods depends largely upon a free and frequent aëration of the filtering material or the soil.

The septic tank is long and comparatively shallow, but should have such a capacity and cross-section that the sewage will pass through at the average rate of about one-half inch per minute, and be almost, if not quite, twenty-four hours in traversing the tank. At the upper end, the fresh sewage enters within a few inches of the bottom of the settling or "grit chamber," which is separated by a partition from the rest of the tank, and in which most of the street sand and other inorganic solids are collected. Thence it goes into the larger space, where the anaërobic bacteria carry on their work.

The tank should be entirely covered in to exclude air and light, for though a thick scum or cake of sludge soon forms on top that would serve this purpose, there is always possibility of it being broken and air admitted by ice, snow, or other causes.

As the sewage passes slowly through the long tank the organic matter is decomposed with the evolution of considerable gas that may be collected and used for heating purposes. In a certain tank about 65 feet long, through which the sewage flowed at a depth of from 7 to 7¼ feet, and at a daily rate of 54,000 gallons throughout the year, it was found that of the 10 grains of mineral and 14.5 grains of organic matter per gallon entering the tank, only 3 grains of mineral and 1.5 grains of organic matter per gallon remained in the sludge, the effluent being quite clear. In other words, after 13 or 14 months, the total solid residue exclusive of moisture from over 20,000,000 gallons of sewage was only 5¼ tons, although approximately 31¼ tons had entered the tank in that time. This represents a reduction of more than 80 per cent. of the total solid matter. Moreover, if this amount of sewage had been treated with chemicals, the sludge or residue would have been about 45 tons.

The outlet from the tank is by a perforated or slotted pipe, located about 2 feet below the sewage surface to exclude light and air, which carries the effluent into a shallow aërating trough over the sides of which the fluid flows in thin sheets and is then led to the aërobic or filtering beds, every opportunity being given for it to take up plenty of air. These beds are filled with porous materials, such as cinders or coke, etc., from ⅛ to ½ inch in size, the idea being that there should be as much capacity for the sewage as possible, and at the same time a ready aëration of the mass when the bed is drained, the beds becoming more efficient after being used some time, as they have thus become impregnated with the right kinds of bacteria. After filling, the beds are left undisturbed for a couple of hours, and are then drained, after which they remain empty for another two hours, it having been found possible by using automatic filling and emptying valves to repeat the process four times daily. It will usually be wise to carry the effluent from the septic tank through at least two of these beds, but if the process is properly accomplished, "by this purification an effluent is obtained which is saturated with dissolved oxygen, which remains entirely inoffensive in smell for an indefinite period in an incubator at summer heat, and which therefore when discharged into a water-course would maintain the respiration of fish, and would never render the water offensive."[1]

Quoting also from Frankland, "The recent experimental work on the bacterial treatment of sewage . . . . shows most conclusively that the best results are achieved by separating the phases in which the bacterial purification takes place, allotting distinct places to the anaërobic and the aërobic organisms respectively engaged on the work.

"The anaërobic bacteria are supplied along with the sewage, and practically no difficulty arises in retaining their services on the works beyond that of providing them with space and time in which to carry on their labors. The aërobic bacteria, however, demand air in addition to space and time, and if this air be not provided in sufficient quanties they go on strike, and leave the works, their place being taken by their less exacting anaërobic brothers, who are, however, unable to finish the work of purification.

"There is, then, the constant tendency for the overflow f the anaërobic bacteria into the aërobic department of works, if there be any stinting of air in the latter. order therefore to insure the services of the aërobic cteria being retained on the premises, it is desirable to rovide for the aërobic bacteria at least two work-shops rough which the sewage, on coming from the anaërobic department, is made to pass.

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[1] Leffmann, "Civic Hygiene," in vol. v. of Cohen's System of Physiologic Therapeutics.

"The first of these aërobic work-shops it may be difficult to provide with adequate ventilation, the result being that both anaërobic and aërobic bacteria will here be found competing with each other, and that the aërobic organisms will be unable to complete the work of purification. The sewage, however, on passing into the second and better ventilated work-shop will there fall almost exclusively into the hands of aërobic bacteria, which it will under proper management leave as an inodorous, almost pellucid liquid incapable of putrefaction."[1]

Another writer summarizes as follows: "As compared with the process of chemic precipitation and sedimentation, the bacterial process presents the following advantages: (*a*) It requires no chemicals. (*b*) It produces no offensive sludge, but only a deposit of sand or vegetable tissue which is free from odor. (*c*) It removes the whole of the suspended matter, instead of only about 80 per cent. thereof. (*d*) It effects the removal of 51.3 per cent. of the dissolved oxidizable and putrescible matter, as compared with the removal of only 17 per cent. effected by the present chemical treatment. (*e*) The resultant liquid is entirely free from objectionable smell, and does not become foul when it is kept; it further maintains the life of fish."[2]

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[1] See Francis Wood's Practical Sanitary Engineering, p. 216.

[2] American Year-book of Medicine for 1900, p. 549.

Electricity has also been suggested as an agency for the purification of sewage, but in most localities is still too expensive for the purpose. In the Webster process iron electrodes are used, and the favorable results are supposed to be due partly to the hypochlorites which are formed from the chlorides always present in the sewage, and partly to the carbonates and oxides of iron, which not only deodorize but also help to oxidize rapidly the organic matters. By this method about 70 per cent. of the putrescible matters and almost all the bacteria are removed from the sewage, but it is still rather costly on account of the large amount of iron consumed.

# CHAPTER XIII.

## MILITARY HYGIENE.

**This** subject is one which has to do with active and presumably healthy men under conditions more or less abnormal and sometimes of a peculiar and unusual stress. Moreover, the actual financial value of the life and health of the individual to the State is more directly manifest than under ordinary circumstances, and, though at times the interests of the former must be sacrificed to those of the latter, it is of the highest economic and practical importance that a government should conserve as far as possible the health and welfare of each member of its army and navy. Consequently, much thought should be and is given to all those questions which rightly come under this head, and the effect of the efforts made in this direction is very decided, especially with reference to the regular or standing armed force of the country.

Men who have become accustomed to military service, and to whom it is a real and permanent business, have probably a better health status than the average citizen, owing to the regularity of their habits and work and to the oversight and care which are given to the details of their life. Conditions are much different, however, when men are suddenly called from many occupations and ways of living to volunteer or militia service. They do not accommodate themselves readily to the change, nor do they appreciate the importance of details that may seem trivial to them but that have great bearing on their future health. Often the utmost efforts on the part of those in authority and who are skilled in these matters are apparently of no avail and lead to undeserved censure. How much more serious actual neglect of hygienic measures may be has been proved more than once in the past.

The following quotation from the Report of the Surgeon-General of the Army for 1899 is pertinent:

"Hygiene is one of the principal subjects of examination for candidates desiring appointment in the medical corps of the army, and at the subsequent examinations for promotions to the grades of captain and major it is given a most prominent place. It is also the most prominent subject in the course of instruction at the Army Medical School, where the student officers spend five hours daily for a period of five months in practical laboratory work relating for the most part to the cause and prevention of infectious diseases; but the comparatively small number of medical officers of the regular army available for duty in the large camps occupied by our volunteer troops at the outset of the war (Spanish-American) proved to be entirely inadequate to control the sanitary situation in these camps."

In a study of military hygiene, all phases of the routine life of the soldier should be discussed, for it is the combination of these that make for good or evil.

Unless the emergency is grave and large numbers of men are needed quickly, much attention should be paid to the selection of the men, and only those enlisted who satisfy certain physical requirements. They should be neither abnormally short nor tall; the weight should be in proper ratio to the height; the vision and general health good, and especially should the chest measurement and expansion or "vital capacity" be considered as of great importance.

"It has also been observed that a close correlation exists between the physical and moral development of men; in fact, lowering the physical means lowering the moral standard of recruits."[1]

Age is also a factor that should be considered. If recruits are too young, they are not able to withstand long-continued work or strain, nor will they be so likely to resist the incurrence of disease. On the other hand, men who are too old will be more liable to have habits of life or taints of chronic disease that will interfere with their military duty, and they will also not serve the maximum length of time that makes their work most economical to the government.

"The medical officer's first duty is rigorously to examine his command, if it has been newly raised, and inexorably to eliminate all men unfit for full military duty. Upon the medical officer who examines recruits for enlistment lies a heavy responsibility, for it practically rests with him to determine the physical efficiency of the command. Unfortunately in time of war, when the necessity for effective men is the greatest, this selection is apt to be devolved upon untrained civilians who have neither the special knowledge that fits them as judges nor the position that enables them in doubtful cases to withstand the constant importunities of still less informed recruiting officers. The careful examination of recruits is not practical hygiene, but the successful application of hygiene requires carefully selected men to secure the best results."[2]

[1] Notter and Firth, p. 917.

[2] Colonel A. A. Woodhull, article on "Military Hygiene" in Reference Handbook of the Medical Sciences.

In selecting the sites for camps or homes of soldiers, consideration must be had as to whether these are to be temporary or permanent, and as to whether the men are to live in tents or barracks. In any case, there should be sufficient space allotted to each command; there should be no interference with the free circulation of air, and the soil should be dry, porous, and readily drained. The ground-water especially should not be too near the surface. Camps should not be located, except in event of grave military necessity, on ground that has been recently occupied by other troops; nor should they be on clay soils, in ravines or valleys where they will receive the drainage from higher ground or other camps, nor near marshes or the marshy banks of rivers, nor where they will receive the winds from malarial districts. Thought should also be given to the source and abundance of the water-supply and its relation to the natural course of drainage from the camp.

If tents are to be used, these must be such as to afford both thorough protection and good ventilation. They should not be too crowded, either as regards the number of occupants in each or the location of the tents one to another. If the camp is of extended duration, the tents should be floored, or at least the men should not sleep on the ground.

A trench should also be dug about each tent to prevent flooding by rains, and from time to time the tents should be moved about, as "it is well known that tents occupying the same ground for a length of time become unhealthy." Camp kitchens, stables, sinks, latrines, etc., should be as far from the sleeping tents as reasonable convenience permits, and to the leeward of prevailing winds. All camps should be regularly and carefully policed, and "the fact that a camp expects to change its position does not justify neglect of proper policing of the ground occupied."

In the regulations and instructions issued in 1895 by the British Quartermaster-General's Department the following points are laid down as of importance:

"1. The length of time troops are to occupy the camping-ground. 2. That order, cleanliness, ventilation, and salubrity are to be insured. 3. That means of passing freely through the camp are essential. 4. That a straggling camp increases labor of fatigue duties, and impedes delivery of supplies and circulation of orders. 5. That the more compact the camp, the easier it is to defend."[1]

If the soldiers are assigned to forts or other permanent encampments, they will probably be quartered in barracks, and these will have been constructed according to specifications. However, it should be remembered that in these attention must be given not only to the comfort of the men, but to their sanitary needs as well, and that the chief faults in such structures in the past have been insufficient ventilation and improper location and arrangement of toilet-rooms, etc.

Barrack buildings should not be more than two stories in height, should be comparatively narrow, should have free ventilation and access of sunlight about them, and should be so placed that they do not interfere with one another in these respects. It will be well if each sleeping-room is planned to contain not more than twenty-five men or a quarter company. Each man should have at least 600 cubic feet of air-space in his dormitory; with ceilings twelve feet high, this will give him fifty square feet of floor-space. Toilet-rooms should be separated from the dormitories by a continually ventilated passage-way, at least; it would be better to have the former entirely apart from the latter.

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[1] Notter and Firth, p. 936.

Kitchens, dining- or mess-rooms, guard-rooms, and quarters for married men should be in separate buildings and apart from the barracks, and these should each be properly arranged for its purpose. The same remarks apply to the post-hospital, which should have as complete an equipment as possible in accordance with the demands of modern medical and surgical science; and consequently, in addition to the general wards, there should be others for the isolation of contagious or infectious cases and for the insane. It goes without saying that the officers' quarters should have every hygienic and sanitary advantage and convenience, both as to construction and location, that the circumstances of the post will permit.

In such permanent encampments, where the accommodations and conveniences more nearly resemble those in the home of the average private citizen, and where proper food, an ample supply of unpolluted water, and suitable arrangements for the removal of wastes and sewage can all be provided for, it will ordinarily not be difficult for the well-informed medical officer to maintain a satisfactory sanitary condition, and, owing to the discipline and supervision of their habits to which the men are subjected, as well as to the fact that they are adults and males, the general health status of the post should usually be better than the average of the neighboring communities.

But conditions and circumstances are much different on the "tented field," and especially so if the command belong to the militia or volunteer service, in which the men have been called from many and various occupations, are unaccustomed to the hardships of military life and the vicissitudes of out-door living, and are unmindful—as they will be at first—of the restraints and value of discipline. Even though the medical officers be well versed in hygienic knowledge and thoroughly aware of the importance of the strict observance of sanitary precautions, and though they have the hearty assistance of the commanding officers, it will take much time so to instruct the men that they will not endanger the health of themselves and others, and eternal vigilance and much effort will be the price of a continuously satisfactory state of affairs.

"In time of war there is added a new army of volunteers, whose men are often accepted without proper scrutiny. The preservation of these men from disease is the chief concern of the medical officer, miscalled the surgeon."[1]

The recent experience of this country in the Spanish-American War is vivid in the minds of every one, especially as regards the sanitary conditions and the epidemic sickness in practically all the camps throughout the country. And while there was much that was censurable, there was still much unjust censure given by those who did not understand to those who did and who strove to the utmost to overcome the untoward and unfortunate conditions.

In August, 1898, a board of medical officers was appointed by the Surgeon-General of the United States Army to "ascertain the causes of the existence and spread of typhoid fever in the national encampments, and to suggest means of its abatement." The results of their work, as epitomized by one of them, Prof. Victor C. Vaughan, in his "Oration on State Medicine" before the annual meeting (1900) of the American Medical

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[1] Colonel Woodhull, loc. cit.

Association,[1] are very instructive and are worth quoting almost entire:

"Every regiment in the United States service in 1898 developed typhoid fever. Typhoid fever not only appeared in every regiment in the service, but it became epidemic, both in the small encampments of not more than one regiment, and in the larger ones consisting of one or more corps. Typhoid fever became epidemic in camps located in the Northern as well as those in the Southern States; and it is so widely distributed in this country that one or more cases are likely to appear in any regiment within eight weeks after assembly. Typhoid fever usually appears in military expeditions within eight weeks after assembly.

"With typhoid fever as widely disseminated as it is in this country, the chances are that if a regiment of 1300 men should be assembled in any section and kept in a camp the sanitary conditions of which were perfect, one or more cases of typhoid fever would develop.

"Neither the miasmatic theory nor the pythogenic theory of the origin of typhoid fever is supported by the investigations, but they confirm the doctrine of the specific origin of typhoid fever. It is disseminated by the transference of the excretions of an infected individual to the alimentary canals of others, and it is more likely to become epidemic in camps than in civil life, because of the greater difficulty of disposing of the excretions from the human body. A man infected with typhoid fever may scatter the infection in every latrine of a regiment before the disease is recognized in himself.

"Camp pollution was the greatest sanitary sin committed by the troops in 1898, and it may be stated in a eral way that the number of cases of typhoid fever in the different camps varied with the method of disposing of excretions. The tub system of disposal of fecal matter as practised in certain divisions is to be condemned, and the regulation pit system is not a satisfactory system of disposing of fecal matter in permanent camps. The Board has recommended that in permanent camps where water-carriage cannot be secured, all fecal matter should be disinfected and then carted away from camp.

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[1] See Journal of American Medical Association, June 9, 1900.

"Some commands were unwisely located, and in some instances the space allotted the regiments was inadequate. Many commands were allowed to remain on one site too long, and requests for change in location made by medical officers were not always granted. Greater authority should be given medical officers in matters relating to the hygiene of camps. Superior line officers cannot be held altogether blameless for the insanitary condition of the camps.

"Infected water was not an important factor in the spread of typhoid fever in the national encampments in 1898. Flies undoubtedly served as carriers of the infection; it is probable that the infection was disseminated to some extent through air in the form of dust; personal contact was undoubtedly one of the means by which it was spread, and it is more than likely that men transported infected material on their persons and clothing, and thus disseminated the disease.

"A command badly infected with typhoid fever does not lose the infection by simply changing location, but when it changes its location it carries the specific agents of the disease in the bodies of the men, in their clothing, bedding, and tentage, and even an ocean voyage does not relieve an infected command of its infection. However, after a command becomes badly infected with typhoid, change of location, together with thorough disinfection of clothing, bedding, and tentage, is necessary.

"Except in case of most urgent military necessity, one command should not be located on a site recently vacated by another, but the fact that a command expects to change its location does not justify neglect of proper policing of the ground occupied.

"It is desirable that soldiers' beds should be raised from the ground, and medical officers should insist that soldiers remove their outer clothing at night when the exigencies of the situation permit. In some of the encampments the tents were too much crowded.

"Malaria was not a prevalent disease among the troops that remained in the United States, and while the investigations show that coincident infection with malaria and typhoid fever may occur, the resulting complex of symptoms does not seem to be sufficiently well defined and uniform to be recognized as a separate disease. The continued fever that prevailed among the soldiers in this country in 1898 was typhoid fever, but in military practice typhoid is often apparently an intermittent disease.

"About one-fifth of the soldiers in the national encampments in the United States in 1898 developed typhoid fever; army surgeons correctly diagnosed a little less than one-half the cases of typhoid fever, and while the deaths from typhoid fever were more than 80 per cent. of the total deaths, the percentage of deaths among cases of typhoid fever was about 7.5. When a command is thoroughly saturated with typhoid it is probable that from one-third to one-quarter of the men will be found susceptible to the disease.

"The belief that errors in diet, with consequent gastric and intestinal catarrh, induced typhoid fever, or that simple gastro-intestinal disturbances predispose to it, is not supported by the investigations. More than 80 per cent. of the men who developed typhoid fever had no preceding intestinal disorder.

"The shortest period of incubation in typhoid fever is probably something under eight days, and one who has lived in a camp in which typhoid fever is prevalent is liable to develop this disease any time within eight weeks after leaving such a camp."

So much has been included in the above quotations, looking in so many different directions, that it would seem that there were little more to say on the subject. However, a few words must be added.

Despite the fact that malaria was apparently not very prevalent among the troops in this country in the late war, it is a disease that is often very harmful and disastrous to armies. So is dysentery and, in other climates or countries, yellow fever and cholera. On account of the recent discoveries regarding the influence of the mosquito in transporting the germs of malaria, yellow fever, and other diseases, a simple mosquito bar or net should be included in the kit of every soldier, and the Surgeon-General's report of 1899 seems to give evidence of its efficacy in preventing such diseases among our soldiers in Cuba. As dysentery and cholera are well known to be transmitted by drinking-water, sanitary precautions as to the care of the water must be observed. Though the quotation above states that "infected water was not an important factor in the spread of typhoid fever, etc.," it must not be inferred that no cases were found to be due to such water. In fact, many cases were undoubtedly thus caused as Vaughan clearly states; but the authorities, early realizing the dangers that might be due to a bad water, made such efforts to obtain pure supplies that other means of infection became relatively more important. Every effort should therefore be made to secure the purest water-supply possible in every military camp, and to have it thoroughly sterilized before use if there is any suspicion of its pollution. A full description of filtration methods and of the sterilizer that has been adopted by the army has been given in the chapter on Water.

As the efficiency of the soldier depends so much upon his food, and as it is of importance for so many different reasons, it is not strange that it has been the subject of the most careful investigation. In fact, much of the scientific knowledge now pertaining to dietetics is the result of the work of the various governments in their efforts to determine the most satisfactory and efficient military rations. Considering the men simply as machines, true economy requires that their food shall be ample in quantity and good in quality. Attention must also be given to its transportation and preparation, and to its character as a source of heat and energy.

A study of the standard daily rations of the various armies of the world at once shows a noticeable uniformity among them in the amounts and relative proportion of the food-principles and in the ratio of nitrogen and carbon. And as these have all had the test of long time and extensive experience, they serve to establish their own scientific accuracy, as well as that of the dietetic ratios which have been determined in other ways and to which they so closely correspond.

No part of a military administration is of more importance than the commissary department, for an army without food is soon worse than useless. But it is not easy to feed properly large numbers of men in an active campaign when the whole body is moving rapidly from place to place and when the exigencies of the day may seem to require all available means of transportation for other purposes. Consequently, much effort has been made to supply rations that are condensed in bulk and that require as little immediate preparation as possible.

Considerable advance in this line has been made in recent years, and various soups, meats, and vegetables, condensed and ready-cooked, are now often supplied when the same cannot be had in a fresh state. That such may be entirely satisfactory cannot be denied, but those in authority must be especially careful as to certain points, viz., that the food is not lacking in quality and that the processes employed have not impaired its dietetic value or digestibility nor permitted harmful changes to take place in it. The temptations of the army contractor are often hard to withstand; moreover, tests have shown that if concentration be carried too far, not only the digestibility, but the nutritive value as well of the food may be seriously impaired. Thus the valuable salts may be lost with the water in the compression of vegetables. Again, the processes may make the foods too uniform in taste, or there may be the omission of such accessories as vinegar, spices, etc., or there may be ignorance as to how to cook them properly; and it must always be remembered that palatability has much to do with digestibility. For these reasons it will be wise to have at least part of the food issued in as nearly the fresh or ordinary state as possible.

Space does not permit consideration of the various articles of food composing the prescribed ration, but it is evident that the laws of dietetics govern here as elsewhere.

It may be well to say, however, that experience seems to show that alcohol should not be included in the regular ration, but should only be issued, if at all, in certain exigencies and in small quantities.

The same principles hold good in regard to soldiers' clothing as for that of other people, but "in selecting the material the chief points to be considered are its permeability, durability, and the property it has of conducting and absorbing heat." It would be well if the undergarments were always in part, at least, of wool. The material of the uniforms and its weight should depend upon the exigencies of the service, considering both the locality and the season of the year. In cold weather wool should, of course, have first place; in hot climates the stout cotton fabric called khaki seems to meet the conditions most satisfactorily. "The color of the material has an important bearing on the hygienic value of the clothing, and in regard to the absorption of heat exerts more influence than the material itself. . . . White possesses very slight absorptive power compared to other colors, and, next to this in the scale, gray or pale yellow gives the best results. Gray is the best color for soldiers' dress on service, for white is least suited to the field, as it soils so quickly. The khaki drill corresponds very closely with gray as regards absorption power."[1]

The clothing should nowhere be so tight as to interfere with respiration or circulation or with free movement of the body. There should be a sufficiency of socks in each man's kit, for "a good sock kept clean, is a protective against sore feet." Boots or shoes should be comfortable as well as durable and waterproof. Leggings may often be used to advantage; they may be of stout canvas, khaki, or leather. Helmets or other head-dress should be light and well ventilated, and of a non-absorbent color. Abdominal bands of flannel are excellent protectives against digestive disturbances, if the men can be induced to wear them. Each kit should contain a rubber or waterproof blanket to protect the soldier from the dampness of the ground at night; it can also be used as a cape in rainy weather. The weight of the kit, arms, accoutrement, etc., is often excessive, and should be kept as light as possible. In some armies as much as seventy pounds is to be carried by each soldier. It should be so divided that, when on the march, as much of this as possible can and should be carried in wagons for the men, they retaining only their arms and water bottles. "Weights are most easily borne when the following points are attended to: 1. They must be as near the centre of gravity as possible. 2. The weights must in no case compress the lungs, or interfere with the respiratory movements or the elimination of carbon dioxide, or hinder the transmission of blood through the lungs, or render difficult the action of the heart. 3. No important muscles, vessels, or nerves should be pressed upon. 4. The weights should be distributed as much as possible over several parts of the body."[1]

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[1] Notter and Firth, p. 955.

The last statement means that the pressure will be most advantageously put upon the tops of the shoulder-blades and upon the hip-bones and sacrum.

The disposal of the wastes of a camp constitutes one of its gravest problems. If it is a permanent post and the men are quartered in barracks with a sufficient water-supply, it may be best to construct a complete sewerage system; but where the encampment is temporary the difficulties are greatly increased. Even though the camp is strictly policed, as it always should be, and the garbage and similar wastes destroyed by fire or burial, there remains the disposal of the excreta of large numbers of men, which, if neglected, is almost certain to become a source of infection.

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[1] Notter and Firth, pp. 961, 962.

The customary sinks are not only liable to pollute the ground-water and perhaps the water-supply of the camp, but they are also a constant offence to the senses, and we now know that infection may be carried by flies directly from them to the food in the kitchens and mess-tents. Where used, their contents should be covered thrice daily with a layer of fresh earth or lime, and when the contents reach within two feet of the surface they should be filled with earth and new ones opened. A medical officer has recently suggested that instead of using earth or lime for a covering, dry grass or straw be spread over the contents and burned two or three times a day. This would not only serve to disinfect the surface and sides of the trench by fire, but the ashes of the straw would form a loose covering of several inches' thickness which would completely conceal the subsequent additions and at the same time effectually protect all the contents from the access of flies. Colonel Woodhull suggests the burning twice a day of small quantities of petroleum poured on the surface of the contents of the sink.

However, it will be wiser to do away with sinks altogether and to provide measures whereby the excreta can be at once chemically disinfected and then removed beyond the limits of the camp. Theoretically, the tub or pail system would seem to be available if proper discipline and supervision could be had; but the recent experience in certain camps rather proves it to be unsatisfactory. Unless the contents are disinfected immediately, the soil about the camp will be almost certainly polluted and infected when the receptacles are removed for emptying, and the flies will also be as numerous as at the sinks. If the tubs should be partially filled before use with a disinfectant, and if they should have close-fitting covers which would only be removed at the time of use, the objections to them would be diminished, but would still remain in part.

The board of medical officers already referred to have recommended, and the Surgeon-General and Adjutant-General have adopted the recommendation, that the excreta be received into a large galvanized iron trough partially filled with an active disinfectant solution, preferably milk of lime on account of its combined efficiency and cheapness. The trough is to be located in a suitable building, and when full or at regular intervals is to be emptied by means of a pumping cylinder into a large water-tight tank on a wagon, similar to the ordinary odorless excavating apparatus. It is probable that such apparatus under proper supervision will prove as efficient and practicable as any that can be devised short of a well-constructed system of sewers involving water-carriage, the installation of which is obviously not feasible in a temporary camp or in one not having an abundant water-supply.

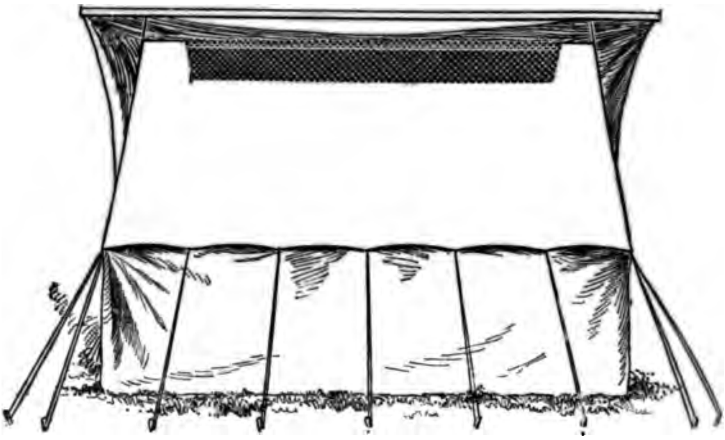
Space does not permit of a full discussion of military hospitals. At permanent posts they may have almost all the equipment and conveniences of the best city hospitals, but in the field in actual service much must be foregone. This often leads to censure from the uninformed and where censure is not deserved. But commanding officers, especially of the medical service, should foresee every emergency and provide for it as far as possible, overrating rather than underrating the probable needs and demands upon the hospital staff, and providing for the comfort as well as the necessities of the sick and wounded. The knowledge that typhoid fever, for instance, is almost certain to occur and become epidemic in any camp of considerable extent or duration should compel preparation for the proper treatment of this disease in so far as this is possible in a field hospital. The trained nurse has proved her value in army hospital work, and has now a place in the regular army medical service. The enlistment and training of a sufficient number of hospital stewards is also of great importance, as is also the instruction of the soldiers themselves as to the care of themselves in emergencies. Undoubtedly this latter instruction, meagre as it has been, and the "first-aid packets" with which each man was supplied, greatly contributed to the excellence of results among the regular troops in the late war.

A thorough course in the fundamental principles of hygiene should be a part of the education of every soldier in the regular army, and especially should this subject be established as one of the most important in the curriculum at West Point. If the graduates and future officers from this great military school were so instructed, it is more than probable that the advice and suggestions of the medical officers of the service would be more often accepted and enforced in the future than they have been in the past.

Hospital tents are apt to be poorly ventilated and oppressive in hot weather or climates. They should have every advantage of location, that the comfort as well as the health of the patients may be conserved. A ventilated hospital tent, devised by Captain E. L. Munson, M. D., U. S. A., has been adopted by the Board of

Equipment on account of its advantages, chief of which are a better ventilation and a lowering of the temperature within to the extent of several degrees.

FIG. 83.



Munson ventilated hospital tent, adopted for United States Army. (The fly thrown back over false ridge-pole to show ventilation opening.)

Another valuable addition to the hospital service of the army has been the purchase and thorough equipment for the purpose of several hospital ships. The saving of life and alleviation of distress made possible by these vessels, when compared with the effects of conditions obtaining in the ordinary transport ships, are incalculable.

The work of the soldier, while excessive at times, ordinarily permits much leisure to the men, which, in turn, is conducive not only to attacks of homesickness and ennui, but to the development of injudicious and injurious habits. Consequently, anything that will profitably employ the attention and activities of the men when off duty is beneficial. For this purpose reading-rooms, athletic sports and the work of various trades may be mentioned. The ability to keep his men pleasantly and advantageously occupied is one of the qualities of a good commander, and medical officers should assist the latter in this respect whenever possible.

The medical officer will also be watchful to guard against the causes of the diseases which are most prevalent in the army, viz., phthisis, heart disease, pulmonary diseases, typhoid, malaria and continued fevers, and, not least in importance, venereal diseases. The latter do much harm in most standing armies, and it is as a prophylactic to these that the occupation of time and energy referred to above is especially advantageous. So, also, must the chief surgeon and his assistants keep oversight of the rations, water-supplies, etc. They must inspect the men at regular intervals, weighing and measuring them, and examining for heart-strain or other circulatory disturbance; they must select suitable places of encampment when on the march, caring for those who are overcome by the heat or exhausted; they must see that the troops do not injudiciously expose themselves when overheated; in fact, they must be fully as zealous and active as the commanding officer to maintain the entire command in its highest physical efficiency.

For further information on this important subject the reader is referred to the article on "Military Hygiene" in the Reference Handbook of the Medical Sciences, by Colonel A. A. Woodhull, M. D., and to the text-book on the same subject by Captain Edward L. Munson, M. D., each of these being in their way models of comprehensive excellence, and having the authority of practical experience.

# CHAPTER XIV.

## VITAL STATISTICS.

SCIENCE is classified knowledge. By arranging known facts and units into groups, and considering them from different points of view, we discover the scope of a particular science, and are also led to the discovery of new facts.

In hygiene it is necessary to have this classification of facts to know what progress we are making, for the true test of any sanitary procedure is its efficacy in preserving health and preventing disease, and we cannot know whether it is efficient or not unless we tabulate and study the results and at the same time eliminate disturbing factors. In this connection it is to be noted that our facts must be accurate and derived from sufficient experience, and that the disturbing factors are especially liable to be numerous.

It is evident that we may study disease by direct observation at the bedside and at the *post-mortem* table, or by experiment; and while our knowledge in the past has been gained principally by the former method, we now, since the advent of modern bacteriology, may further investigate many diseases by reproducing them in susceptible animals. In this way we soon learn that some diseases are much more preventable than others, and we endeavor to discover the respective causes and predisposing conditions of each that we may the more readily estimate their effects and take measures to restrict and prevent their action.

Our observations may be of two kinds: 1. By noting and comparing individual cases, or by following the track of a particular outbreak or epidemic. 2. By observing large classes and groups of men, which necessitates a record of births, marriages, diseases, and deaths. The consideration of such records constitutes the study of **vital statistics,** the most important object of which is, as Billings says, "to give warning of the undue increase of disease or death presumed to be due to preventable cause, and also to indicate the localities in which sanitary effort is most desirable and most likely to be of use." The reader will also notice how the study of vital statistics broadens out into the science of demography—the study of the life of people and communities.

The national census reports now give statistical returns not only for the wards and other political divisions of some of our large cities, but also for so-called "sanitary districts," in which the population is chiefly made up of those of marked racial or other characteristics that influence the vital problem. The study of such returns supplies much information and the explanation of many otherwise obscure phenomena in the vital statistics of a municipality.

At this point it will be well to note certain elementary principles which must be observed in any statistical inquiry, in order that the results of that inquiry may have any value whatever. These are:

1. Our facts, or *numerical units,* must have precise, definite, and constant characteristics. For example, in tabulating the death-rate or sick-rate from typhoid fever, every case used in the calculation must be accurately

diagnosed and must be undoubtedly one of that disease. If there is any doubt as to preciseness, it is better to omit that unit.

2. The units are to be arranged into *groups*. These groups must have dividing characteristics so definite that there can be no doubt into which group each unit will come. No unit must be in more than one group at one time. It is difficult to group complex facts so as to analyze them properly and to discover all possible phases.

3. Having decided and arranged the groups, we must have a *constant numerical standard* by which the relation of the various groups to the total units may be expressed. It is generally 100 or some multiple of 100.

4. We must determine the *variation* in the proportion or relation of the component groups to the whole in similar series of cases. While only an approximation to an invariable proportion may be had in any one series, it may be shown mathematically that as the number of units in the series increases there is a greater probability that the proportions will remain the same, and that we may calculate the limits of variation by Poisson's formula, as follows: If $m$ be the number of units in one group in the formula $m + n = q$, and $n$ the number in the other, the proportion of $m$ to $q$ will be $\frac{m}{q}$, and of $n$ to $q$, $\frac{n}{q}$, and these proportions will vary in succeeding series within the limits indicated by $2\sqrt{\frac{2mn}{q^3}}$. Consequently, the greater the value of $q$, the less comparatively will be that of $2\sqrt{\frac{2mn}{q^3}}$, or the limit of variation from $\frac{m}{q}$ and $\frac{n}{q}$.

Example: Suppose that in a series of 1000 cases of diphtheria 700 recover; then, according to the above formula, the limit of variation in the next series of 1000 similar cases would be 40, and the recoveries would be between 660 and 740; whereas, in a like series of only 100 cases the limit of variation would be 13 and the probable recoveries would vary between 57 and 83.

The *arithmetical* mean is usually employed in medical inquiries, though the increase in population is estimated by geometrical progression. The *probable error* or variation from the arithmetical mean is about two-thirds (0.6745) of the *mean error*, which latter is the *mean of the mean error in excess and the mean error in deficiency.* The mean error in excess is the difference between the mean of the series and the mean of all the units of the series above the mean. The mean error in deficiency is the difference between the mean of the series and the mean of all the units below the mean.

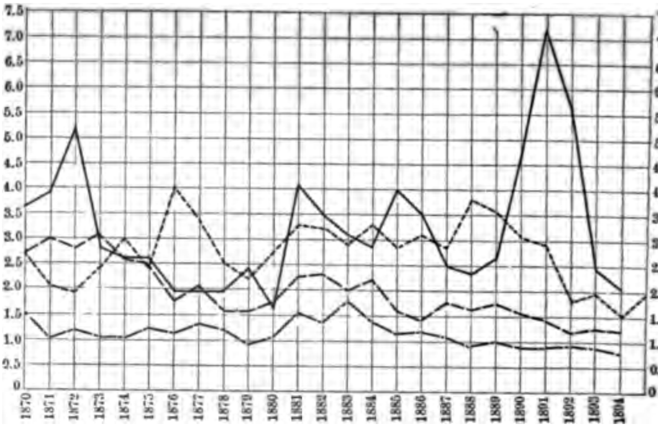
The relative value of two series is as the reciprocals of the squares of their probable errors. Thus if the probable error of series A is 10 per cent. and that of B is 2 per cent., the value of A to B will be as $\frac{1}{100}$ to $\frac{1}{4}$, or B will be twenty-five times as valuable as A.

The relative value of two or more series is also as the square roots of the numbers of units in the respective series. From the above it is evident that the results from an average cannot be absolutely applied to any particular case, for there is always the chance of such variation as may be determined by Poisson's formula or by the estimation of the probable error. We apply averages to the aggregates of facts, and they will approach exactitude if they are founded on a sufficient number of facts. We must be careful in estimating the value of means and averages and in giving credit or blame accordingly. Guy says: "Averages are numerical expressions of probabilities; extreme values are expressions of possibilities."

Statistical results are frequently expressed by graphic representations (see Fig. 84), and these are very valuable, especially for class or similar demonstration.

The numerical units employed in the study and the calculations of vital statistics are persons living and persons dead, and the groups into which these units are classified are characterized by such distinctions as age, sex, occupation, locality, etc. The sources from which we derive our information regarding these units are two, viz., the *census* or count, which every civilized country makes periodically, and the returns of births, marriages, deaths, and

FIG. 84.



Graphic chart, showing percentages of typhoid-fever deaths in total mortality in four cities. Unbroken line, Chicago; lower line, New York; short dashes, Philadelphia; long dashes, Boston.

cases of contagious disease made to local governing sanitary bodies, such as boards of health, etc. These latter returns localize the units and help especially in the classification in which locality is a factor.

The census returns give not only the population, but also particulars as to sex, age, race, occupation, etc. Of these the age-record is most important, as the death-rate varies most according to age.

The *natural increment* of a population is the excess of births over deaths, but the *actual increment* differs from this, however, according to the difference between emigration and immigration. And as the rate of increase does not always remain the same, estimates of population at times other than of the census cannot be exactly accurate. Thus, we may have a lowered death-rate and yet a decrease in both the natural and actual increment, owing to a greatly lowered birth-rate and to increased emigration, both of which may be primarily due to a long period of oppression or financial distress. However, to estimate the population for times other than the census year, we assume that the rate of increase, whether positive or negative, that prevailed between the last two census enumerations will continue until the next is taken.

Now, as populations increase in regular geometrical progression when the rate of increase is constant, which we assume, it can readily be shown that

logarithm $R = \frac{1}{10}(\log. P' - \log. P)$, where R is the annual ratio of increase, P the population of the census before the last, and $P'$ the population of the last census. If we now multiply the logarithm of R, the annual ratio of increase, by the number of years since the last census, and add to it the logarithm of the last census (log. $P'$), we will have the logarithm of the population at the middle of the given year—*e. g.*,

$$8\,\frac{(\text{log. of the pop. }1890 - \text{log. pop. }1880)}{10} + \text{log. pop. }1890$$

= logarithm of the population on June 30, 1898.

For the reasons already given, such an estimate will not be absolutely accurate, and it would, consequently, be well to have a census taken every five years for certain data. The more accurate the estimate for any year happens to be, the mere reliable will be the statistical results. It is also to be noted that in this country the census is taken at the middle of the year, and that death-rates, etc., are based on the population estimated, as above, for the middle of the given year.

We may also estimate the population from the number of houses and use this as a check on the above estimate. The number of persons living in each house averages about the same for each city, but differs for different cities. Local authorities always tend to overestimate the population, and a police census is invariably too high. Another method of approximately estimating the population in small and slowly increasing districts is to add to the population of the last census one-tenth of the difference between it and the population of the preceding census for every year since the last census.

As has been stated, we get the number of births, marriages, deaths, etc., from the registration records, the proper data being furnished to the registration bureau by duly authorized persons. For instance, the law should require a burial permit for each death in order to identify the person and to guard against criminal acts or neglect, and the death certificate on which the burial permit is issued should give the name, sex, color, age, occupation, and especially the cause of death of the deceased. The diagnosis concerning this last item should be as correct as possible, and the primary as well as the secondary cause of death should be given. And while it is difficult to determine the actual cause of death in many cases without a *post-mortem* examination, there is fortunately not much uncertainty usually in diagnosing the diseases of which we most want statistical information, especially the so-called preventable or infectious diseases.

As a consequence of the above, the certificate as to the cause of death will need to be signed by some one competent to determine that cause, viz., by an educated physician; and it is therefore necessary that the State should define who is and who is not an "educated physician." And as this information and the other required returns which the physician makes, as well as his professional services in general, are for the sake and benefit of the citizens of the State, it is evidently to the State's interest that it be very careful and explicit as to the qualifications of the physicians whom it allows to practise within its borders.

Another reason for the enforced return of a certificate and the issuance of a burial permit for every death is that this is about the only way in which it is possible to secure a record of all the deaths. Any system for collating the list of deaths only at the end of the year will omit from 25 to 40 per cent. of the number.

The statements made in the introductory chapter and elsewhere show the importance of vital statistics in determining the sanitary conditions and improvement of communities. In order that comparisons and correct judgments may be readily made, it is evident that all classifications, returns, and registrations should be on a basis or system as uniform as possible, but almost the opposite has obtained, since almost every State, city, or local authority has used its own system and without any concert of action until comparatively recently. Accordingly, in order to amend this and to secure not only uniform, but also correct and thorough returns from the whole country, the Division of Vital Statistics of the U. S. Census Office is making extraordinary efforts to bring about uniform legislative requirements in the various States and to secure the adoption of the International Classification of Causes of Death, which is intended "to harmonize the features of the most generally used systems in order to afford a common basis of union," and has been adopted by the U. S. Census Office for the compilation of mortality statistics. To this end circulars have been sent to every physician "describing the details required by the Standard Certificate of Death (see opposite page), and giving the titles of the International Classification of Causes of Death, with explanatory notes showing the significance of various terms to the titles under which they are compiled, and a list of indefinite and unsatisfactory terms very frequently used in reporting deaths, with a statement of why such statements are unsatisfactory." This circular is very instructive, and its recommendations should henceforth be observed by all physicians in making death returns.[1]

The gross death-rate varies with the size of the community. Newly settled communities have a lower death-

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[1] This circular can doubtless be had on application to the Division of Vital Statistics of the Census Office at Washington, together with a circular on Medical Education in Vital Statistics, relating to the instruction of medical students in registration methods, uses of registration data, and the duties and obligations of physicians; and one on Practical Registration Methods, for the information of local registrars.

8—209. **MARGIN RESERVED FOR BINDING.**

V. S. No. 98. **Write Plainly, with Unfading Ink—this is a Permanent Record.**

N. B.—Every item of information should be carefully supplied. **AGE** should be stated **EXACTLY. PHYSICIANS** should state **CAUSE OF DEATH** in plain terms, that it may be properly classified. The "Special Information" for persons dying away from home should be given in every instance.

**PLACE OF DEATH.**
County of ........................................

## CENSUS OFFICE.
## STANDARD CERTIFICATE OF DEATH.

..............................................................

Registered No. ....................

*City of .............................................(No. ............................................................St.; .....................Ward.)†

**FULL NAME** ............................................................

### PERSONAL AND STATISTICAL PARTICULARS.

**SEX** | **COLOR**

**DATE OF BIRTH**
...................................................1...........
(Month) (Day) (Year)

**AGE**
.......................*years*, .....................*months*, ....................*days*

**SINGLE, MARRIED, WIDOWED, OR DIVORCED**

**BIRTHPLACE**
(State or country)

**NAME OF FATHER**

**BIRTHPLACE OF FATHER**
(State or country)

**MAIDEN NAME OF MOTHER**

**BIRTHPLACE OF MOTHER**
(State or country)

**OCCUPATION**

**THE ABOVE STATED PERSONAL PARTICULARS ARE TRUE TO THE BEST OF MY KNOWLEDGE AND BELIEF**

(Informant) ............................................................

(Address) ............................................................

Filed ............................................................
.......................190........................................
*Registrar*

### MEDICAL CERTIFICATE OF DEATH.

**DATE OF DEATH**
.........................................................................190.......
(Month) (Day) (Year)

**I HEREBY CERTIFY,** That I attended deceased from
...........................190.......to.......................................190..........
that I last saw h..........alive on..................................190.........,
and that death occurred, on the date stated above, at..........
___M. The **CAUSE OF DEATH** was as follows:
............................................................................
............................................................................
.............................................................(DURATION)..............DAYS
Contributory ............................................................
.............................................................(DURATION)..............DAYS
(Signed)...........................................................................M. D.
.....................190......Address ............................................

**SPECIAL INFORMATION** only for Hospitals, Institutions, Transients, or Recent Residents.

Former or Usual Residence ............................ How long at Place of Death?......Days

Where was disease contracted, if not at place of death? ..........................................

**PLACE OF BURIAL OR REMOVAL** | **DATE OF BURIAL**
.............................190.......

**UNDERTAKER** | **ADDRESS**

C—277

* If death occurs away from USUAL RESIDENCE, give facts called for under "Special Information."

† If death occurred in a Hospital or Institution, give its NAME instead of street and number.

Reduced copy of Standard Certificate of Death recommended by the United States Census Office.

rate than older ones, because the proportion of adults is larger and of children smaller in the former. With large communities and short periods the probabilities of error are very great, and the longer the period the less likelihood of error. Birth-rates, marriage-rates, and death-rates are usually calculated as rates per thousand of the population living at the middle of the given year, and are determined by multiplying the number of births, marriages, or deaths by 1000, and dividing the product by the population.

Fair death-rates are 9 to 16 per 1000 in rural districts and small villages; 14 to 18 per 1000 in towns of 5000 to 20,000; 17 to 20 in cities of 25,000 to 100,000, and 18 to 21 in cities of over 100,000. If the death-rates are much lower than this, the chances are that the population has been overestimated or that all deaths have not been recorded. If more than this, there is probably some special cause for the high mortality.

In statistical computations we must exclude the populations and deaths in hospitals, prisons, etc., except for such of the inmates as belong to the district in which such institution is located.

To find the weekly or daily death-rate, the number of deaths for the week or day must be multiplied by 1000 and divided by the so-called weekly or daily population: the weekly population $= \frac{\text{total population}}{52.17747}$; the daily population $= \frac{\text{total population}}{365.24226}$. The monthly population equals the daily population multiplied by the number of days in the month.

The zymotic death-rate is the rate from the seven principal zymotic or infectious diseases, viz., smallpox, measles, scarlatina, diphtheria, whooping-cough, fever (typhoid, typhus, or other continued fever), and diarrhœa.[1] It is given per 1000 of population, and in the same way we can give the special rate for any particular disease. For example, the average annual zymotic death-rate for England and Wales for the decade from 1861 to 1870 was 4.11, for 1871–80 it was 3.36, and for 1881–90, 2.30—a striking proof of the decided benefits following proper attention to hygiene and sanitation.

The mortality from certain diseases is affected by age, sex, race, occupation, density of population, seasons, cyclical changes, etc.

Contrary to the general rule, the *rate of infant mortality* is not expressed per thousand of population, but measured by the proportion of deaths of infants under one year to the births registered in that year, and is determined by multiplying the number of deaths by 1000 and dividing the product by the number of births.

The infant mortality-rate is always high owing to various causes, viz., early marriages and weakly parents, hereditary tendencies or diatheses, insanitary surroundings and unfavorable social conditions, improper feeding, insufficient clothing, infant life insurance, etc.

Death-rates vary greatly for the different ages, being much higher for the first five years of life. For this reason it is well to express the death-rate of children under five as the rate per thousand of children under that age, rather than as a percentage of the total number of deaths. Otherwise, a town with a large number of children might apparently have an abnormally high death-rate. There might also be a difference in the death-rates of two localities due to sex-distribution, for the sexes differ in their susceptibility and resistance to the various diseases. More boys are born everywhere than girls, but more males die than females, so that the tendency is to a preponderance of the latter, except in newly settled countries or localities. Age-distribution and sex-distribution favor a low mortality in rapidly increasing towns, new localities, and manufacturing districts; in rural districts they tend to increase the death-rate.

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[1] Wilson, Handbook of Hygiene, 8th edition, p. 570.

Consequently, when the death-rates of two or more towns or localities are to be compared, there must be corrections for age-distribution and sex-distribution. The mean annual death-rate of the country for the decade preceding the last census for each age and sex is applied to the town or district, with age-distribution and sex-distribution according to the last census. The total number of deaths thus calculated, multiplied by 1000, and divided by the population of the last census, gives the *standard death-rate* of that town. The mean annual death-rate of the country divided by the standard death-rate gives the *factor for correction*, which being multiplied by the recorded death-rate of any year gives the *corrected* death-rate. The *comparative mortality figure* is determined by multiplying the corrected local death-rate by 1000 and dividing by the death-rate for the whole country, and only indicates that the same population which gave 1000 deaths in the whole country gave or would have given so many deaths in the town or district in question.

The morbidity-rate or sick-rate of a community is difficult to estimate, since there is usually no complete record and registration of cases of disease. Where returns are required to be made of the infectious diseases, the morbidity due to them may be determined in the same way as the mortality for the locality. It is estimated that there is a total of about two years' sickness in a community for every death, and members of beneficial societies are said to average about one and one-half weeks' sickness annually. In this connection, the following definitions are given of terms that are employed in discussions of vital statistics, especially in relation to longevity:

The *mean age at death* of a population is the average age at which death occurs in that population, and is indicated by the total of the ages at death divided by the number of deaths. Inasmuch as it depends largely on the age-distribution of the population, it is neither a good test of longevity nor of sanitary conditions, except when it is calculated or taken from life-tables for an entire generation.

The *probable duration of life* is the age at which any number of children born will be reduced one-half, the chances thus being even that each will survive to that age.

For a million children the probable duration of life is for males less than forty-five years; for females, forty-seven years.

The *mean duration of life* is the same as the mean age at death when the population is stationary as to age-distribution and sex-distribution. Otherwise, it is indicated by the mean after-lifetime.

The *expectation of life* is the *mean after-lifetime* of a person at any age, as indicated by a life-table; or, in other words, it is the average number of years which persons of that age continue to live. At birth it is identical with the mean duration of life, and "as applied to communities, it is the mean lifetime of a generation of persons traced by the life-table method from birth to death, and is the only true test of the health of populations." According to Farr, "a life-table is a barometer which indicates the exact measure of the duration of life under given circumstances, and is indispensable in gaugi influence of sanitary or insanitary conditions."

The essential factors of a life-table are the numb ages of the living and the number and ages of tho die, and these factors are obtained from the mean lation for each age and sex and from the total returns between two censuses.

# CHAPTER XV.

## THE EXAMINATION OF AIR, WATER, AND FOOD.

IN this final chapter the author has endeavored to arrange a series of methods for the examination or analysis of the subjects respectively considered, in such a manner that any one who has had a little laboratory experience may be enabled to determine their hygienic conditions, sanitary influence, or degree of purity, and this at the cost of a minimum of time and expense.

The methods outlined have been selected from a variety of sources, and some have been especially modified for the purpose; so that while it is not claimed that they will give the absolutely accurate results desired by the professional bacteriologist or chemist, nor that they will suffice as a basis for expert testimony in court or to establish legal rights, it is believed that, if carefully carried out, they will not fail to yield the information sought for, viz., whether the sample of air, water, or food examined is sanitarily pure or safe for use within the accepted limits.

Only such apparatus is to be used as can be readily obtained or improvised without much expense, and every effort has been made to render everything clear to the student and reader, so that he may not hesitate to undertake the necessary investigation whenever occasion requires or an opportunity offers.

For further details regarding any of the methods, should these be found necessary, reference may be made to the text-books indicated, as they will render clear any points that may here seem uncertain or abstruse.

## Air.

The solid impurities in the atmosphere may be collected for microscopical examination as follows: Tightly cork a large glass funnel and fill it with cracked ice. As the aqueous vapor of the air condenses on the exterior, the dust particles adhere to the moistened glass, and are carried down by the condensed water into a vessel placed below, in which they are allowed to settle. From this they are transferred by means of a pipette to clean slides and examined under the microscope. Dixon's apparatus may often be used advantageously, especially where it is desired to examine the dust in the air of a number of localities within a short time. In this the air from the respective places is drawn successively over cover-glasses which have been coated with gelatin or glycerin, and on which the dust particles are deposited and adhere till they may be examined microscopically or bacteriologically.

To make a qualitative bacteriological examination the air may also be drawn through sterilized glass tubes coated interiorly with gelatin. Bacteria and their spores, moulds, etc., adhere to this coating, and from each individual or group of individuals colonies develop, from which pure cultures and subsequent bacteriological experiments may be made; or the sterilized gelatin may be exposed in flat (Petri) dishes to the air for a short time to allow the bacteria, etc., to fall on the surface. The tubes or dishes are then covered and set aside to allow the colonies to develop.

To make a quantitative bacteriological examination a known quantity of air may be drawn through a small tube filled with sterilized and pulverized sugar. The sugar is then transferred to tubes or flasks of melted and sterilized gelatin, and dissolving leaves the bacteria, etc., free to develop in the gelatin, which may be poured upon sterilized glass plates or Petri dishes before cooling. A temperature just sufficient to melt the gelatin will not be too warm to harm the bacteria. The number of colonies that develop may be assumed to represent the number of living micro-organisms in the volume of air drawn through the tube.

**Test for Carbon Dioxide, $CO_2$.**—*Boom's Modification of Wolpert's Method.*—Make a mark on any test-tube, say one inch from the bottom. Fix the bulb of an atomizer to a glass capillary tube sufficiently long to reach to the bottom of the test-tube, and in such a manner that a definite quantity of air is forced from the bulb through the tube at each compression. To use: Fill the test-tube exactly to the mark with a saturated solution of lime-water, take the apparatus into the out-door air and find out how many compressions of the bulb are needed, driving the air slowly through the lime-water each time, to make the lime-water just turbid enough to obscure a pencil-mark on white paper placed beneath the test-tube and viewed from above. Then rinse out the test-tube, fill exactly to the mark again with lime-water, and repeat the process in the room the air of which is to be examined. We then assume that the out-door air contains the normal amount of carbon dioxide—0.04 per cent. (unless we happen to know the actual amount in the atmosphere at the time), and estimate the percentage of carbon dioxide in the air of the room by the following proportion: Let $x$ = the percentage of $CO_2$ in the air of the room. *Then the number of compressions of the bulb required in the outer air is to the number of compressions required in the room as*

*$x$ is to 0.04.* If the actual percentage of $CO_2$ in the outer air is known, substitute this for the 0.04 per cent. in the formula. Care must be taken in using this device not to draw any of the lime-water into the bulb.

*A Modification of Angus Smith's Method.*—To a moderately large, wide-mouth bottle (one quart) fit a perforated rubber stopper, the perforation being just large enough to admit the tip of a 1 c.c. pipette; first fill the bottle with the air of the room by filling it with water and then emptying it in the room; fit in the stopper and introduce 1 c.c. at a time of a standardized alkaline solution, slightly colored with a few drops of a neutral alcoholic solution of phenolphthalein; close the perforation with a piece of glass rod and shake the bottle well after each addition of the alkali, noting when the color ceases to be discharged by the $CO_2$ of the contained air. Then, since the quantity used of the alkali solution indicates a certain definite amount of $CO_2$:

*The number of c.c. used multiplied by the amount of $CO_2$ each c.c. represents, multiplied by* 100, *and divided by the capacity of the bottle in c.c. less the number of c.c. of solution used* $= x =$ the percentage of $CO_2$ in the air examined.

A suitable alkaline solution may be prepared as follows: Dissolve exactly 2.409 grammes of pure sodium carbonate (free from the water of crystallization) in 1 litre of distilled water. Only a fraction, say one-fourth or one-tenth, of this quantity need be made up at a time. Each c.c. of this solution is equivalent to 1 c.c. of $CO_2$. For use: To 10 c.c. of this solution add a few drops of neutral alcoholic solution of phenolphthalein and dilute to 100 c.c. Each c.c. of this dilute solution is then equivalent to 0.1 c.c. of $CO_2$, and used as above will give close results. The phenolphthalein is used as an indicator, as it loses its color as long as the $CO_2$ is absorbed and the alkalinity of the soda solution is destroyed. The stock solution should be kept in well-filled, tightly stoppered bottles.

Example: If 9 c.c. of the above dilute solution be used, and the capacity of the bottle is 1200 c.c., then

$$\frac{9 \times 0.1 \times 100}{1200-9} = \frac{90}{1191} = x = 0.0755,$$

the percentage of $CO_2$ in the air of the room.

*Pettenkofer's Method.*—Into a large clean bottle filled, as above, with the air of the room, 50 c.c. of a clear solution of lime (or barium hydrate) are introduced, the bottle stoppered and then well shaken so that the air may be thoroughly mixed with the lime-water. The strength of the lime-water, being unknown, is determined by means of a solution of oxalic acid of such a strength that 1 c.c. corresponds in alkalinity to 0.5 c.c. of $CO_2$. (Such a solution is made by dissolving exactly 2.84 grammes of pure crystallized oxalic acid in 1 litre of distilled water.)

Into 25 c.c. of the stock lime-water in a beaker this acid solution is run from a graduated burette until the alkalinity of the lime-water is just destroyed, the neutral point being indicated either by means of a few drops of phenolphthalein solution in the beaker or by turmeric paper, the latter being colored brown and the phenolphthalein retaining its color as long as the solution is alkaline. When the lime-water is exactly neutralized, the exact amount of the acid solution used is noted. Then, after the time necessary to allow the complete absorption of the $CO_2$ in the testing bottle by the lime-water therein, viz., eight to ten hours, 25 c.c. of that lime-water are measured into a beaker, and the alkalinity exactly

determined as above by means of the oxalic acid
tion.

Now, inasmuch as part of the alkalinity of the
water which was in the bottle has already been ne
ized by the carbon dioxide in the air of the bottle, i
require less of the acid solution to neutralize the
water from the bottle than was required for the
quantity of stock lime-water, and as 1 c.c. of the
solution corresponds to 0.5 c.c. of $CO_2$, the differen
the amounts of acid solution used expressed in c.c
express the number of c.c. of $CO_2$ in the volume c
in the bottle.

For, though each c.c. of acid solution is equivale
only 0.5 c.c. of $CO_2$, the loss of alkalinity of only
half the lime-water primarily introduced into the b
has been determined, and the total loss of alkalinity w
have to be expressed by multiplying 0.5 c.c. $CO_2$ by
the difference in c.c. between the amount of acid us
testing the stock lime solution and that used in te
the 25 c.c. (one-half) of lime-water from the bottle.
twice $0.5 = 1$. Therefore, the difference between
readings in the two tests gives the amount of $CO_2$ in
bottle having been thus determined and the capacit
the bottle found by measuring the quantity of wate
air in the bottle. The quantity of carbon dioxide in
will hold, the percentage of carbon dioxide in the
examined is readily determined.

Example: 25 c.c. of stock lime-water require 30
acid solution; 25 c.c. of lime-water from bottle req
27 c.c. of acid solution.

Therefore, 30 c.c. $-$ 27 c.c. $=$ 3 c.c. $=$ amount of car
dioxide that was in the air in the bottle, which cont
(for example, say) 2550 c.c.

Then $\frac{3 \times 100}{2550 - 50} = \frac{300}{2500} = 0.12$ per cent. $CO_2$ in the air of the room at current temperature and pressure. To be absolutely exact in the result, correction must be made by reducing the results to the standard temperature and barometric pressure, but this is unnecessary in most cases.

The absorption of the carbon dioxide gas is more rapid if a solution of barium hydrate is used instead of the lime-water, the former taking up the gas in an hour or so instead of eight or ten, as with the lime-water, but the latter is usually much more readily obtained, and therefore more likely to be used.

## Water.

To test for color, turbidity, etc., compare with distilled water, using tall glass jars and looking down through equal depths upon a white surface. The smell of a water may be detected by heating it to about 140° F. for a few minutes in a glass-stoppered bottle. This test may or may not indicate fecal contamination. Few polluting impurities, when only in moderate quantities, give any taste to water, and a dangerously polluted water may have a good taste. Iron in small quantities, one-fourth of a grain to a gallon, will give a taste to the water.

Use caution in tasting suspicious waters. Aëration is indicated by the lustre of the water and by the presence of air-bubbles on the sides and bottom of the vessel.[1]

**Test for Chlorine.**—*Solutions required:* 1. Standard nitrate of silver solution: to 1 litre of pure distilled water add 4.788 grammes of pure silver nitrate; 1 c.c. of this solution is equivalent to 1 m.g. of chlorine. 2. Potassium chromate solution—a 5 or 10 per cent. solution of potassium chromate made up in distilled water free chlorine.

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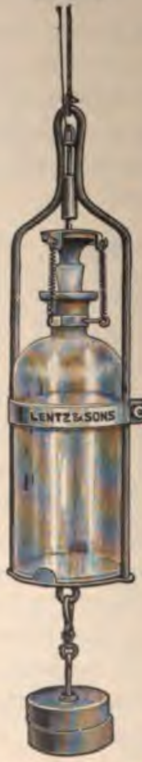
[1] See also pages 205 to 210.

*Process.*—To 100 c.c. of the water add a few drop potassium chromate solution, and then run in fro burette or graduated pipette the silver solution, adding drop by drop, and stirring the water with a glass r Continue until a faint but permanent orange-red tint h

FIG. 85.



Bottle for collecting samples of water at different levels.

been produced, showing that all the chlorine has combined with the silver, the persistent reddish color being due to silver chromate. The number of c.c. of silver solution used indicates the number of milligrammes of chlorine in 100 c.c., or parts per 100,000; this multiplied by 10 gives the number of milligrammes in 1 litre, or parts per 1,000,000. If the water contains but little chlorine, accuracy will be furthered by evaporating 250 c.c. of the water to 50 c.c. over a water-bath, and proceeding as above; the result multiplied by 4 will give the amount of chlorine in 1 litre.

**Test for Nitrates.**—*Solutions required:* 1. Phenolsulphonic acid: 6 grammes of pure carbolic acid; 37 c.c. of strong sulphuric acid, and 3 c.c. of distilled water. 2. Standard potassium nitrate solution: add 0.722 gramme of fused potassium nitrate to 1 litre of distilled water. Each c.c. of this solution contains 0.1 m.g. of nitrogen as nitrates. The water used in making the solution must be free from nitrates.

*Process.*—Evaporate 10 c.c. of the water to be examined (or 25 c.c. if it is presumably low in nitrates) just to dryness. Add 1 c.c. of phenolsulphonic acid, stir with a glass rod, and add 1 c.c. of distilled water and 3 drops of strong sulphuric acid; warm, and add 25 c.c. of distilled water, being careful not to dissociate and drive off any of the nitrates by too prolonged or intense heating; then add ammonia until the fluid is strongly alkaline, and dilute with water to 50 c.c.

Treat 1 c.c. of the standard solution in an exactly similar manner and compare the tints produced, placing them in two Nessler or other tubes of equal calibre, and diluting the darker until the tints match exactly, and calculating the amount of nitrogen present by the amount of dilution necessary—*e. g.*, in testing a certain sample, the tint from 1 c.c. of standard potassium nitrate solution is darker and requires the addition of 50 c.c. more water —*i. e.*, up to 100 c.c. Therefore, 100 c.c. : 50 c.c. : : 0.1 m.g. N : $x = 0.05$ m.g., the amount of nitrogen as nitrates in the 10 c.c. of water examined. The test is based on the fact that the phenolsulphonic acid is converted by the nitrates into picric acid, which forms ammonium picrate upon addition of the ammonia, thus giving a yellow tint to the water. The amount of picric acid and picrate formed and the consequent depth of color therefore depend on the amount of nitrates present in the water.

**Test for Nitrites.**—*Solutions required:* 1. Sulphanilic acid: dissolve 0.5 gramme ot sulphanilic acid in 150 c.c. of dilute acetic acid, sp. gr. 104. 2. Naphthylamine acetate: boil 0.1 gramme of solid naphthylamine in 20 c.c. of distilled water, filter through a plug of washed absorbent cotton, and mix the filtrate with 180 c.c. of dilute acetic acid. 3. Standard sodium nitrite solution: dissolve 0.275 gramme of pure silver nitrite in pure water and add a dilute solution of pure sodium chloride until a precipitate ceases to form, and dilute to 250 c.c. with pure water. For use, dilute 10 c.c. of this stock solution to 100 c.c. Each c.c. of the dilute solution contains 0.01 m.g. of nitrogen as sodium nitrite. Keep the solutions in the dark when not in use. All water in these solutions must be free from nitrites; likewise all water used in the tests, except the sample under examination.

*Process.*—Place 25 c.c. of the water to be examined in a cylindrical vessel, and in a similar vessel of the same calibre dilute 1 c.c. of the (diluted) standard sodium nitrite solution to 25 c.c. with nitrogen-free distilled water; add to each vessel 2 c.c. of first one and then the other reagent, using a separate pipette for each; compare the colors at the end of five minutes and estimate the amount of nitrites by diluting the darker tint until it matches the lighter, and comparing the respective volumes, as in the test for nitrates; the result will give the quantity of nitrogen as nitrites in the water, and should not be more than a trace. The above test is a very delicate one.

*Schuyten's Method.*[1]—"When 5 c.c. of a 1 per cent. solution of antipyrin in acetic acid (1 : 10) is added to a solution containing nitrites, a green color is produced." Measure 45 c.c. of the water to be examined into a Nessler tube, and in another of equal calibre mix 1 c.c. of the standard sodium nitrite solution (dilute) with 44 c.c. of distilled and nitrite-free water. To each tube add 5 c.c. of the antipyrin solution. Allow to stand for one-half hour and compare as above.

"This method will show the presence of 1 part of nitrogen as nitrous oxide in 20,000 parts, and while not so delicate as the other method, is not hindered by the presence of any of the ordinary contaminations in water."[2]

**Test for Hardness.**—*Solutions required:* 1. Soap solution: dissolve 10 grammes of castile soap in 1 litre of weak (35 per cent.) alcohol. 2. Standard lime solution: dissolve 1.11 grammes of chemically pure calcium chloride in 1 litre of distilled water: 1 c.c. of this solution is equivalent to 1 m.g. of calcium carbonate.

*Process.*—Ascertain how much soap solution is required to make a standard lather with 100 c.c. of distilled water, as follows: Place the water in a flask holding about 250 c.c., and run in the soap solution from a burette, a few drops at a time, corking and shaking the flask well after each addition; the lather should have a depth of at least one-fourth of an inch and be permanent for not less than five minutes. Then standardize the soap solution by diluting 5 c.c. of the standard lime solution to 100 c.c. with distilled water, and determine how many c.c. of the soap solution are required to make a permanent lather as above with it; this quantity, less the number of c.c. needed to make a lather with 100 c.c. of distilled water, represents the amount of soap solution that will neutralize 5 m.g. of calcium carbonate or its equivalent. Lastly, determine in the same way the number of c.c. of soap solution necessary to make a permanent lather with 100 c.c. of the water to be examined; again subtract the quantity of soap solution requisite to make a lather with 100 c.c. of distilled water, and estimate the amount of calcium carbonate or its equivalent present, as follows—*e. g.*, it takes 2 c.c. of soap solution to make a lather with the distilled water, and 12 c.c. with the diluted standard lime solution; then 12 c.c. — 2 c.c. = 10 c.c., which is equivalent to 5 c.c. of the standard lime solution, and accordingly each c.c. of the soap solution is equivalent to 0.5 c.c. of the standard lime solution, or to 0.5 m.g. of calcium carbonate; consequently, if 100 c.c. of the water examined require 17 c.c. of soap solution, it must contain $(17 - 2) \times 0.5 = 7.5$ m.g. of calcium carbonate or its equivalent, or 75 m.g. to the litre.

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[1] Bergey's Handbook of Practical Hygiene, p. 95.

[2] Ibid.

**Tests for Lead, Copper, and Iron.**—To 50 or 100 c.c. of water in a white porcelain dish, or in a tall glass jar over white paper, add a few drops of ammonium sulphide; a dark coloration or precipitate indicates the presence of either lead, copper, or iron, due to formation of their respective sulphides. Then add a few drops of hydrochloric acid: if the color disappears, iron only is present; if it persists, lead or copper is present. In the latter case add a few drops of acetic acid and about 1 c.c. of a strong solution of potassium cyanide: if the color disappears, it is due to copper; if it persists, it is due to lead. If lead only is present, the above test will detect one-tenth of a grain per gallon. The above tests may be corroborated as follows: Partly fill two test-tubes with the original water. To one add a little potassium chromate solution: an opacity and the deepening of the color to canary yellow indicate lead. To the second add a drop of hydrochloric acid and a few drops of potassium ferrocyanide solution: a blue color indicates iron, in either the ferrous or ferric form; a bronze or mahogany-red color indicates copper.

Quantitative tests for the above metals may be made by making standard solutions of the respective elements or some of their salts, treating a measured quantity of the original water with the proper reagent as indicated above, and comparing the color produced with that given by a definite quantity of the respective standard solution.

**Test for Phosphates.**—*Solutions required:* Ammonium molybdate: dissolve 10 grammes of molybdic anhydride in 41.7 c.c. of ammonia (sp. gr. 0.96) and pour slowly into 125 c.c. of nitric acid (sp. gr. 1.20); allow to stand in a warm place for several days until clear.

*Process.*—Slightly acidulate 500 c.c. of water with nitric acid, evaporate to 50 c.c., and add a few drops of ferric chloride and ammonia to slight excess; filter, dissolve the precipitate in the smallest possible quantity of nitric acid and evaporate to 5 c.c.; heat nearly to boiling, add 20 c.c. of ammonium molybdate solution; keep the solution warm for one-half hour. If there is an appreciable quantity of precipitate, collect it on a small weighed filter-paper, wash with distilled water, dry at 100° F., and weigh. The weight of the precipitate multiplied by 0.05 gives the amount of phosphorus tetroxide ($PO_4$) in the 500 c.c. of water.

**Test for Free and Albuminoid Ammonia.**—*Wanklyn's Method.—Solutions required:* 1. Standard ammonium chloride solution: dissolve 0.382 gramme of pure dry ammonium chloride in 100 c.c. of ammonia-free water. For immediate use dilute 10 c.c. of this standard stock solution up to 100 c.c. with ammonia-free water; each c.c. of the dilute solution contains 0.01 m.g. of nitrogen as ammonia. 2. Alkaline potassium permanganate solution: dissolve 200 grammes of potassium hydrate (in sticks) and 8 grammes of potassium permanganate in 1 litre of distilled water, evaporate to about 750 c.c. to drive off the ammonia present, and make up to 1 litre again with ammonia-free water. To make ammonia-free water, add about 1 grain of sodium carbonate to 1 litre of distilled water and boil until about one-fourth is evaporated. 3. Nessler's reagent: dissolve 1.5 grammes of potassium iodide in 10 c.c. of distilled water and 1.7 grammes of mercuric chloride ($HgCl_2$) in 30 c.c. of distilled water; add the mercuric chloride solution to the potassium iodide until a permanent precipitate is formed, and then dilute to 100 c.c. with a 20 per cent. solution of sodium hydrate, add the mercuric chloride solution till a permanent precipitate again forms, and allow to stand until clear; this reagent gives a brown or yellowish-brown coloration if ammonia be present in water, and improves on keeping.

*Process.*—Place in a retort 500 c.c. of the water to be examined, connect with a condenser, and boil gently so that the water may distil over slowly. The retort and condenser should have been thoroughly rinsed with ammonia-free water. Collect the distillate, 50 c.c. at a time, in Nessler tubes, add 2 c.c. of Nessler's reagent to each 50 c.c., and determine the amount of ammonia or nitrogen in each as follows: Place in another Nessler tube 50 c.c. of ammonia-free water and 2 c.c. of Nessler's reagent, run in from a burette the dilute standard ammonium chloride solution until the color exactly matches that of the first 50 c.c. of the distillate. Repeat the process for each 50 c.c. of distillate until the test shows no more ammonia is coming over from the retort. The total amount of (dilute) ammonium chloride solution used indicates the total amount of nitrogen of the *free ammonia*. Usually all the free ammonia will come over in the first 150 or 200 c.c. of distillate. Compare the colors by looking down through the tubes on a white surface. If the first 50 c.c. give a precipitate with the Nessler reagent, it must be diluted and the amount of nitrogen estimated from the diluted distillate. The free ammonia being determined, allow the retort to cool and add to the water remaining in it 50 c.c. of the alkaline permanganate solution. This converts a certain proportion of the nitrogenous organic matter of the water into ammonia; distil as before, estimating the amount of nitrogen in each 50 c.c. of the distillate until ammonia ceases to come over. The amount of ammonium chloride solution thus used will indicate the nitrogen of *albuminoid ammonia*, and the total amount of ammonium chloride solution used in the whole process gives the nitrogen of the free and albuminoid ammonia in 1 litre of water.

The importance and relative value of the results of the foregoing tests in determining the purity or safety of a drinking-water, have been given in Chapter V. on pages 210 to 213, inclusive.

## Food.

**Milk.**—*Good Milk.*—**Characteristics: ivory white, opaque, neutral or slightly alkaline reaction, no sediment, no unusual or offensive taste or odor, specific gravity 1029 or above; cream, 10 to 40 per cent. by volume; fats, 3 per cent. or more; total solids, 12.5 per cent. or more.**

**Water is indicated by low specific gravity and by low percentage of cream.**

**Skimming is indicated by a slightly raised specific gravity (2°), by a low percentage of cream, and by a poor color, though the deterioration in color may be disguised by the addition of annotto, etc.**

Watering and skimming are indicated by lowered specific gravity, by low percentage of cream, and by poor color.

The specific gravity is determined by the lactometer, in using which correction must be made for temperature, provided the latter varies much from 60° F., the standard.

The percentage of cream is determined by the cream gauge or creamometer; the milk should be allowed to stand in the creamometer for at least eight to ten hours, and should be covered.

A very high percentage of cream tends to lower the specific gravity theoretically; but when a milk is rich in fat it is also rich in solids not fat.

An acid reaction, unless very slight, indicates souring of the milk or the addition of some preserving acid. A strongly alkaline reaction indicates the addition of some substance like chalk, sodium carbonate, etc., to increase the specific gravity. Such addition is verified by an excess of total solids, and by the effervescence of the latter —after drying—upon the addition of a drop or two of hydrochloric acid.

*To determine the percentage of total solids:* Weigh a small evaporating dish, preferably platinum, add 5 to 10 c.c. of milk, and weigh dish and milk to get weight of milk; evaporate to dryness over a water-bath, completing the drying in a water-oven until there is no further loss of weight; weigh dish and contents (total solids); subtract weight of dish, multiply by 100, and divide by weight of milk. Result: the percentage of total solids.

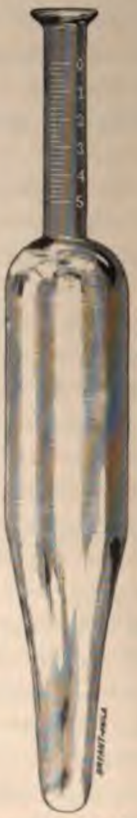
*To determine the percentage of ash:* Ignite the total solids over a naked flame until all black specks have disappeared; cool and weigh; multiply weight of ash by 100, and divide by weight of milk. Result: percentage of ash.

*To determine the percentage of fats:* Proceed as above with 10 c.c. of milk, and evaporate until the residue is a tenacious pulp, extinguish the flame, fill the dish half-full of ether, stir and triturate the residue thoroughly with a glass rod, decant the ether and filter it through a small filter-paper, reserving the filtrate; add more ether to the residue, stir and triturate as before, and filter, repeating the process three times or till the residue is perfectly white; wash the filter-paper well with ether, collect the latter and add to the preceding filtrate; evaporate the ether filtrate until only the fat remains and its weight is constant; weigh the fat, multiply by 100, and divide by the weight of the milk. Result: percentage of fat.

This method when carefully performed is said to be fully as accurate as the extraction (Soxhlet) method, and does not require the more expensive apparatus of the latter. If the residue from which the fat has been exhausted is carefully dried on a water-bath at 100° C. until there is no further loss by evaporation, its weight will be that of the "solids not fat" of the milk.

*Centrifugal method:* Where a centrifuge is availa
use, the following method for the fat-determinati

FIG. 86.



Bottle for determining percentage of fat by means of the centrifu

be found to give results that are probably accura
within 0.2 per cent. of fat:

Two solutions are necessary: 1. Fusel oil, 37 wood or methyl alcohol, 13 c.c.; hydrochloric acid, 50 c.c. 2. Sulphuric acid, sp. gr. 1.83.

Into the milk bottle, which is made to fit the centrifuge and which has a long graduated neck, 5 c.c. of the milk to be examined are introduced by means of a pipette, and to this 1 c.c. of the alcohol solution (1) is added and the mixture well shaken by hand. The sulphuric acid is then added, little by little, with frequent shaking, until the bottle is filled to the topmost (zero) graduation. It is then rapidly whirled in the centrifuge until only the fat occupies the neck as a clear layer, when the actual percentage can be read from the graduations. When the milk is very rich—*i. e.*, containing more than 5 per cent. of fat—it will be necessary to dilute the milk with an equal volume of water, and then to multiply the result by 2. Likewise, cream should be diluted with 4 parts of water and the result multiplied by 5. The same principle is employed in the Babcock and other cream-testers now largely used by dairymen, etc.

*The extraction method:*[1] "About 10 grammes of milk are carefully weighed in a glass or porcelain capsule and mixed with about 10 grammes of freshly ignited sand, pumice-stone, or asbestos, and evaporated to dryness on a water-bath. The dish with its contents is then finely pulverized and transferred to a Soxhlet extraction apparatus and the fat extracted with ether for at least five hours. The ether extract of the fat is then evaporated to dryness on a water-bath and the residue dried to constant weight (at 100° C.) and weighed. The increased weight of the flask (of the Soxhlet apparatus) will represent the fat in the 10 grammes of milk."

A Soxhlet apparatus is so constructed that a quantity of ether is repeatedly evaporated and condensed in it without loss, the condensed ether being made to percolate through substances placed in the upper part of the apparatus and to extract therefrom soluble matters, such as fat, which are collected in a small flask below, and from which the ether can finally be evaporated.

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[1] Bergey's Handbook of Practical Hygiene, p. 129.

*Test for annotto:* A percentage of cream considerably lower than the color of the milk would indicate justifies the suspicion that some coloring-matter has been used. This is frequently annotto.

Coagulate one ounce of milk with a few drops of acetic acid and heat; strain, and press out the excess of liquid from the curd; triturate the curd in a mortar or dish with ether, decant the ether and add to it 10 c.c. of a 1 per cent. solution of caustic soda; shake, and allow to separate; pour off the upper layer into a porcelain dish, put in two small disks or strips of filter-paper; evaporate gently: annotto will dye the disks an orange or buff color. Moisten one disk with dilute solution of sodium carbonate to fix the color; touch the other disk with a drop of stannous chloride: annotto will give a rich pink color. This test is sensitive to 1 part of annotto in 1000 of milk, and with milk in any condition.

*Test for boric acid:* Upon igniting the total solids, boric acid or boron gives a greenish tinge to flame. Place in a porcelain dish 5 c.c. of milk, 1 drop of strong hydrochloric acid, and 2 drops of a saturated tincture of turmeric. Dry on a water-bath, remove as soon as dry; cool, and add 1 drop of ammonia on a glass rod. A slaty-blue color, changing to green, is given if borax is present. This test will show $\frac{1}{1000}$ grain of borax. Less will give the green color, but not the blue.

*Test for salicylic acid and salicylates* (Bergey): Dilute the milk (100 c.c.) with an equal bulk of distilled water at 60° C.; precipitate with 8 drops of acetic acid and 8 drops of a solution of mercuric oxide in nitric acid; shake and filter. To the filtrate add 50 c.c. of ether, which takes up the salicylic acid; decant, and filter the supernatant ether. Evaporate this filtrate nearly to dryness, and add a few drops of highly diluted neutral ferric chloride. A violet color indicates the presence of salicylic acid, the depth of color increasing with the amount.

To test for salicylic acid in butter, it is first treated with sodium carbonate and the homogeneous mixture acidulated with sulphuric acid, and then shaken with a mixture of equal parts of ether and petroleum ether, after which the supernatant ether is filtered off and treated as above.

*Test for formaldehyde* (Bergey): Add an equal volume of water to the milk or butter to be tested, place in a flask on a steam-bath and distil over about one-fourth the total volume. Treat 10 c.c. of the distillate with 2 drops of ammoniacal silver solution (made by dissolving 1 gramme of silver nitrate in 30 c.c. of distilled water and adding ammonia until the precipitate that first appears is redissolved, then diluting to 50 c.c. with water). If formaldehyde is present, it causes a black cloud in the distillate after standing for several hours in the dark.

Harrington gives the following test among others: "Mix in a porcelain dish 10 c.c. each of milk and hydrochloric acid (sp. gr. 1.2) and 1 drop of ferric chloride solution. Heat and stir vigorously. If formalin has been added, a violet color will appear before the boiling-point has been reached, varying in intensity according to the amount present. This process is exceedingly delicate and will detect 1 part in 500,000 in the fresh condition."[1]

According to Hehner, "no formaldehyde could be detected at the end of a week in a sample (of milk) to which had been added 1 part in 100,000; after two weeks none could be detected in a sample of 1 part in 50,000; and after three weeks only a faint trace could be detected in a sample of 1 part in 25,000."[2]

**Butter and Oleomargarine.**—Pure butter should have good taste, odor, and color; it should not be rancid, and should not contain too much water or salt, nor should it have any added coloring-matter. The average composition should be about as follows: fat, 82 per cent.; casein, 2 per cent. (not over 3 per cent.); ash or salts, 2 per cent.; water, 13 per cent. Butter fat is a compound of glycerin with certain fatty acids, some of them volatile and soluble in hot water, others non-volatile and insoluble in hot water.

Oleomargarine consists of ordinary animal or vegetable fats, melted, strained, cooled with ice, worked up with milk, colored, and salted. The fats are usually beef or mutton fat, lard, or cotton-seed, palm, or cocoanut oil. If care and cleanliness are observed in the manufacture, oleomargarine is not harmful or innutritious, but it should not be sold as butter.

Fraud is to be detected by observing the difference in composition and properties of the *fats*. For instance:

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[1] For other tests for formaldehyde, see Harrington, pp. 108, 109, and Leffmann and Bevan's Food Analysis, pp. 220–222.

[2] Leffmann and Bevan, loc. cit.

| BUTTER FAT. | BEEF FAT, ETC. |
|---|---|
| 1. The specific gravity is very rarely below 910, never below 909.8. | 1. Beef fat, etc., is never above 904.5. |
| 2. The soluble, volatile fatty acids average between 6 and 7 per cent., never below 4.5 per cent. | 2. Rarely more than $\frac{1}{2}$ per cent., never above $\frac{3}{4}$ per cent. |
| 3. The insoluble fatty acids form about 88 per cent. of the total weight of butter fat. | 3. Generally about 95 per cent. |
| 4. The melting-point of the fat varies from 86° to 94° F.; is usually from 88° to 90° F. | 4. Rarely, if ever, above 82° F. |
| 5. Is readily and completely soluble in ether. | 5. Less so and leaves a residue. |
| 6. Under the microscope pure butter fat consists of a collection of small oil globules, with an occasional large one. | 6. The contours of the small oil globules are less distinct, and the larger ones are more numerous and irregular in size. |
| 7. No crystals, except when the fat has been melted. | 7. Crystals of the non-volatile acids are often seen. |

*To determine the specific gravity of butter fat:* Melt a quantity of the butter in a beaker in a water-bath at about 150° F. When the fat is perfectly clear and transparent, carefully decant the fat from the lower stratum of water, curd, and salt into a fine filter; collect the filtrate and pour into a specific gravity bottle, which has been previously weighed, both when empty and when filled with distilled water at 100° F. See that the bottle is exactly full of the fat, wipe clean, and weigh when the temperature is as near 100° F. as possible, because solidification soon begins below this temperature. Subtract the weight of the bottle, divide by the weight of the water which the bottle contains, and multiply by 1000; the result is the specific gravity.

*To find the melting-point:* Pour a little melted fat into a small test-tube $(2'' \times \frac{1}{4}'')$ and cool. Partly fill two beakers of unequal size with cold water; place the test-tube in the smaller (taking care to allow no water to mix with the fat), and the smaller in the larger, and gently heat the outer beaker. Suspend a thermometer in the smaller, near the test-tube, and note the temperature when the fat *begins* to melt; this is the melting-point.

*To determine the percentage of insoluble (non-volatile) fatty acids:* To 6 grammes of butter fat add 50 c.c. of alcohol containing 2 grammes of caustic potash (KHO) and boil gently for fifteen or twenty minutes to saponify the fat. Dissolve the soaps thus formed in 150 to 200 c.c. of water, and decompose with about 25 c.c. of dilute hydrochloric acid. The separated fatty acids are poured upon a weighed filter-paper, washed with 2 litres of boiling water, dried at 95° to 98° C. and then weighed. The weight of these insoluble fatty acids should not be over 90 per cent. of the weight of the butter fat.

**Flour and Bread.**—*Wheat Flour.*—Characteristics: almost perfectly white, smooth and free from grit; no mouldy or unpleasant odor; cohesive when lightly compressed; no signs of parasites under the microscope; water less than 18 per cent.; ash less than 2 per cent.

"The roller process yields a slightly rough flour, and the hard winter wheat may give a yellowish tinge. Good flour is slightly acid to test-paper, but not to the taste, and an acidity that may be recognized by the senses means a change. Acid flour means sour bread, and any disagreeable taste or odor indicates bad flour. When boiling water is poured on a little flour, there should arise no odor but that of freshly ground wheat."[1]

*To determine the percentage of water and ash:* In a weighed platinum (or porcelain) dish place about 50 grammes of flour, weigh, and dry over a water-bath for

[1] Colonel A. A. Woodhull, M. D., article on "Military Hygiene," in The Reference Handbook of the Medical Sciences.

an hour or so; then complete the evaporation in a water-oven until there is no further loss of weight; weigh, subtract this weight, less the weight of the dish, from the original weight of the flour. Multiply the remainder by 100 and divide by the original weight of the flour. The result is the percentage of water. Then ignite the dried flour in the dish and incinerate till there are no longer any black particles and only the ash remains; cool, weigh, subtract weight of dish, multiply the remainder by 100, and divide by the original weight of the flour. The result is the percentage of ash.

*To determine the percentage of gluten:* By means of a glass rod mix a weighed quantity of flour with a *little* distilled water into a stiff dough; then repeatedly wash away the starch and soluble constituents, kneading the dough with the rod or fingers, and continuing until the wash-water comes away clear; the gluten and a small amount of fat and salt remain. Spread on a weighed dish or crucible lid, dry in a water-oven, and weigh; multiply by 100 and divide by the original weight of the flour. The result is the *approximate* percentage of gluten. The gluten should pull out into long threads; otherwise, it is poor.

"The relative strength and elasticity of the gluten, which are determined comparatively by manipulating a small quantity of flour intimately mixed with half its weight of water, make a standard for comparison. This is known as the dough-test, and its failure shows weak flour, from poor wheat or imperfect milling and defective gluten."[1]

An excess of water impairs the keeping quality and lessens the amount of nutriment in the flour. An excess of ash indicates the addition of mineral substances. A deficiency of gluten may also indicate that the flour is not pure wheat flour. Parasites and fungi are especially likely to be found in old, damp, or inferior flour.

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[1] Colonel A. A. Woodhull, M. D., loc. cit.

*To test for mineral substances:* Shake a little flour in a test-tube with some chloroform, and allow it to stand for a few minutes. The flour floats and any mineral matter sinks to the bottom, when it can be removed with a pipette and examined under a microscope.

*Wheat Bread.*—Characteristics: fairly dry, light, and spongy; clean and nearly white; of pleasant taste; not sodden, acid, or musty; ash not over 3 per cent.; no parasites or mouldiness; no flour other than wheat; but little, if any, alum; no copper sulphate.

*Test for alum:* Add 5 c.c. of a 5 per cent. tincture of logwood and 5 c.c. of a 15 per cent. solution of ammonium carbonate to 25 c.c. of water; soak a crumb of the bread in this for a few minutes; drain and gently dry: alum is indicated by a violet or lavender color; its absence by a dirty-brown color on drying.

*Test for copper sulphate:* Draw a glass rod that has been dipped in a solution of potassium ferrocyanide across a cut slice of the bread: copper is indicated by a brownish-red streak.

*Test for ergot in flour or bread:* Add liquor potassæ; a distinct herring-like odor (due to propylamine) is appreciable if ergot be present.

An excess of water, an unnatural whiteness, and a low percentage of ash in bread indicate the addition of rice. Potatoes give an increased percentage of water and an alkaline ash.

For further tests and details in work pertaining to a laboratory of hygiene the reader is referred to Fox's Examination of Food, Air, and Water; Kenwood's Hygienic Laboratory; Bergey's Handbook of Practical Hygiene; Harrington's Practical Hygiene; and Leffmann and Bevan's Food Analysis.

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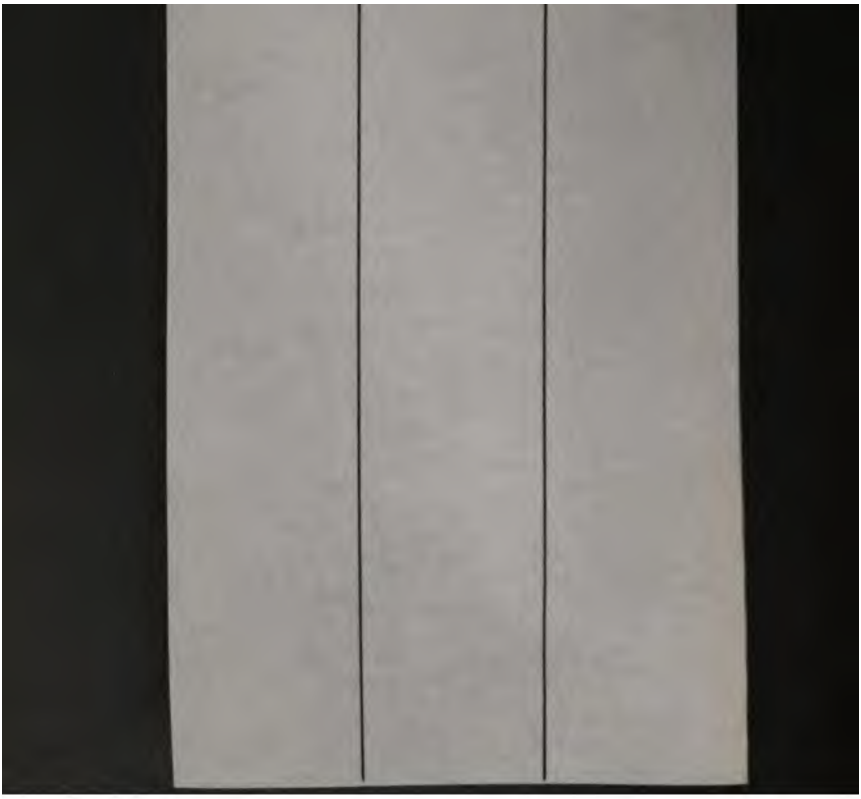

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